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The American Midland Naturalist

Devoted to Natural History, Primarily that of the Prairie States

Founded by J. A. Nieuwland, C.S.C.

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VOL. 21 MAY, 1939 No. 3

A Survey of the Herpetology of Great Smoky Mountains National Park*

Willis King

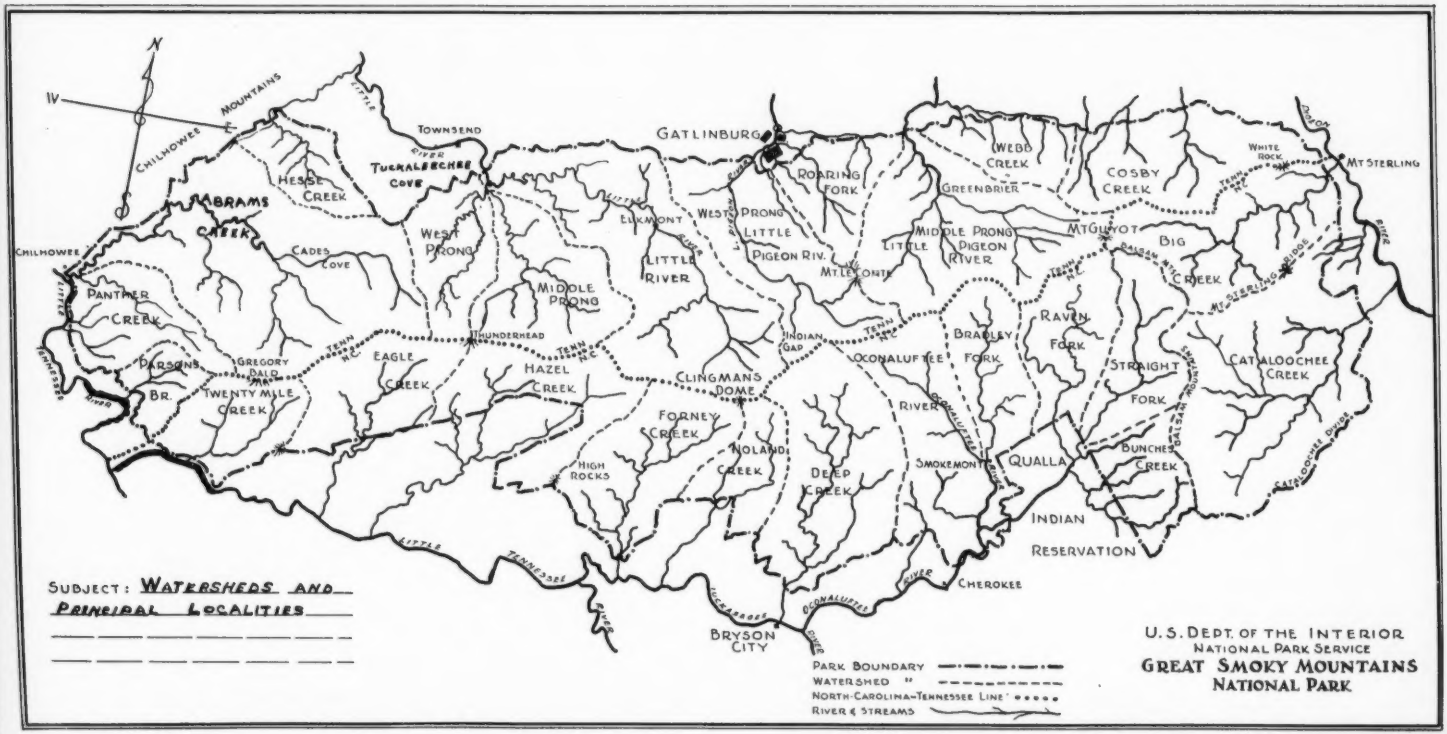
This report deals with the occurrence and distribution of 70 species, representing 36 amphibians and 34 reptiles. Fourteen of the amphibians and 18 of the reptiles are reported from the Great Smoky Mountains for the first time. The records of occurrence combine those given in earlier literature and the results of field collecting by the author and his associates from June, 1934, to October, 1938. Undoubtedly as further work is done, the species list as well as the distribution of the known forms will be enlarged. This is brought out by the fact that during the last 8 months of the present study, 5 species not previously taken were added to the list and 3 others found in earlier collections. It is recognized that a survey of this nature can never be complete, and the present paper is presented only as a summation of the information up the present time.

Geographical Area Treated

The Great Smoky Mountains consist of one high divide with numerous lateral ridges, extending from the Pigeon River on the east to the Little Tennessee on the west. The crest of the ridge is the North Carolina-Tennessee State Line. The main axis of the park is generally east and west, and approximately 54 miles long. The north-south width of the park varies from 10 to 19 miles, while the foothills of the Great Smokies extend some 5 miles beyond the park boundary on the north side and 1 to 3 miles on the south side. The lowest point in the park is at the mouth of Abrams Creek at approximately 850 feet elevation. The top of Clingmans Dome at 6,642 feet is the highest.

The Great Smoky Mountains are unsurpassed throughout the north temperate zone in the variety and abundance of their living forms. Although this paper is primarily a report on the fauna of the park proper, collections have been made in adjacent territory and important additions to the lists thereby obtained. The Little Tennessee, Tuckasegee and Oconalufty Rivers and the Cataloochee Divide have formed the southern boundary for the

* This is a copy of the dissertation submitted to the Graduate School of the University of Cincinnati in partial fulfillment of the requirements of the degree of Doctor of Philosophy, May 31, 1938.


N
IV
CHILHOWEE MOUNTAINS
TOWNSEND
GATLINBURG
TUCKALEECHEE COVE
HESSE CREEK
ABRAMS CREEK
CHILHOWEE
CADES COVE
WEST PRONG
LITTLE RIVER
ELKMONT
WEST PRONG LITTLE PIGEON RIV.
MT LECONTE
ROARING FORK
WEBB CREEK
GREENBRIER
COSBY CREEK
WHITE ROCK
MT STERLING
MIDDLE PRONG LITTLE PIGEON RIVER
MT GUYOT
BIG CREEK
PANTHER CREEK
MIDDLE PRONG
THUNDERHEAD
INDIAN GAP
RAVEN FORK
BRADLEY FORK
STRAIGHT FORK
CATALOOCHEE CREEK
PARSONS BR.
GREGORY BALD
TWENTY MILE CREEK
EAGLE CREEK
HAZEL CREEK
CLINGMANS DOME
OCONALUFTEE RIVER
FORNEY CREEK
NOLAND CREEK
HIGH ROCKS
DEEP CREEK
SMOKEMONT
QUALLA
BUNCHES CREEK
INDIAN RESERVATION
LITTLE TENNESSEE RIVER
CHEROKEE
BRYSON CITY
SUBJECT: WATERSHEDS AND PRINCIPAL LOCALITIES
PARK BOUNDARY
WATERSHED "
NORTH CAROLINA-TENNESSEE LINE
RIVER & STREAMS
U.S. DEPT. OF THE INTERIOR
NATIONAL PARK SERVICE
GREAT SMOKY MOUNTAINS
NATIONAL PARK

purposes of this study. On the west and northwest Chilhowee Mountain is a natural barrier to the earth-bound species. Collections have not been made on Chilhowee Mountain east of Little River. Only a few collections have been made north of the park boundary, these principally in Tuckaleechee Cove and near Gatlinburg. The Pigeon River from the State Line to Waterville Lake forms the eastern boundary of the area studied. This report probably does not include all the species which occur in the foothills area surrounding the park and may occasionally penetrate the Great Smoky Mountains proper.

Previous Work

Because the Great Smokies were so inaccessible until very recent years, the herpetological work done in the region has been limited. However, the fame of the area as a collecting ground, especially for salamanders, has spread widely. Blatchley described *Plethodon jordani* and *Gyrinophilus danielsi* in 1900 from specimens collected at Indian Gap, on the State Line. Dunn (1926) in his monograph of the Family *Plethodontidae* lists several species from the Great Smokies, but actually entered the area only at Mount Sterling. Pope (1928) spent a day or two in the vicinity of Bryson City and Andrews Bald. McClure (1931) studied the salamanders of LeConte Creek, but reports only 6 species. Weller (1931), made the first list of the salamanders from the area, recording 12 species. Necker (1934) reported 7 frogs, 2 lizards, 10 snakes and 2 turtles, mostly from the vicinity of Greenbrier. Harper (1935) recorded a few of the common species of frogs and toads from Gatlinburg and Bryson City, both of which localities border the park. King (1936) described *Desmognathus wrighti* from Mount LeConte.

In addition to the above reports which deal specifically with the Great Smoky Mountains, several workers have studied the amphibians and reptiles of the Southern Appalachians, particularly western North Carolina. Cope (1870, 1889, 1898-1900), reported some of the species of the Southern Appalachians. Brimley (1912), contributed "Notes on the Salamanders of the North Carolina Mountains. . . .," wherein *Plethodon metcalfi* and *Pseudotriton ruber schencki* were first described. Dunn (1916) collected in the Blue Ridge and reported on the "Reptile and Amphibian Collections from the North Carolina Mountains. . . ." Pope (1924) contributed valuable life history data on several of the Plethodonts, particularly *Desmognathus phoca, D. quadra-maculatus* and *D. fuscus carolinensis*. Noble (1927) studied the life histories and evolution of several of the Plethodonts occurring in western North Carolina. Bailey (1937) contributed several locality records for species of Genera *Plethodon* and *Eurycea*. In addition there have been many papers dealing with the life histories of species that occur in the park, but which are beyond the scope of this paper to report.

Distribution and Relationship of Orders

Among the amphibians and reptiles, the salamanders of the Family *Plethodontidae* alone have been sufficiently collected and studied to give a

clear idea of the species occurring here, and there are many gaps even in this group. Although much is yet to be learned, the present paper will help throw some light on the faunal relationships encountered in the region. Problems of origin, dispersal, and the influence of diastrophic movements have only partially been described and explained. Even though some information might be available which pertains to one group of plants or animals, such as the salamanders, there has been no evidence whether that holds true for any other group, the snakes for example.

Caudata

Of the 25 species of salamanders known to occur at Great Smoky Mountains National Park, 20 belong to the Family *Plethodontidae*. At least 10 of these are strictly Appalachian species. One, *Plethodon jordani*, has not been reported outside of the Great Smokies. The lunglessness of this Family is generally attributed to an early adaptation to a mountain brook habitat, and the center of origin placed in the Southern Appalachians. This gives increased importance to this region, and necessarily requires that all the Plethodonts listed actually refer back to this area, at one time or another in their history. Dunn (1923) in writing on some of the problems of geographical distribution of amphibians, states, "All this leads to one conclusion: that the *Plethodontidae* originated in and have dispersed from the mountains of the eastern United States, in a word Appalachia. We have arrived at this result irrespective of the fact that the primitive forms are at present restricted to Appalachia, by arguments from the center of the range, from the origin in mountain brooks (the anatomy), and from the present position of the mountain brook forms (the ecology." True, many of the species have abandoned the mountain brook habitat for a near-terrestrial existence, and have migrated from the area, but their history can be traced in many cases and their origin placed in the Southern Appalachian area.

Salientia

The frogs and toads occurring in the park are on the whole, species widespread over eastern United States. The presence of *Pseudacris nigrita feriarum*, an Appalachian Mountain species, and *Gastrophryne carolinensis* from the Piedmont and southern Mississippi provinces are of special note. Other typically southern frogs and toads are absent.

Lacertilia

Three of the 8 species occurring are widespread in their geographical range and five are southeastern in their distribution. The *Eumeces* complex, composed of species *E. fasciatus, laticeps* and *inexpectatus*, and the presence of *Anolis carolinensis* are of special note.

Serpentes

The snakes rival the salamanders in number of species represented, and offer a very interesting composition of forms. Nine of the species can be

classed as widespread in distribution. Southeastern United States contributes a total of 6 or 27 per cent of the snakes, in contrast to the 3, or 12 per cent of all salamanders derived from those provinces. There are no snakes present which might be considered principally Appalachian in distribution. The absence of lowland races of *Elaphe*, *Lampropeltis*, *Natrix* and *Coluber* is interesting. The snake population in East Tennessee deserves further study, because it is a meeting ground of so many northern and southern, eastern and mid-western subspecies. Jones (1928) lists 30 snakes as occurring in Tennessee but gives no locality records.

Testudinata

The Testudinata are represented by only 5 species. Two of these are general over eastern United States, one is a Mississippi Valley species, one an eastern form, and one jointly occupies the Tennessee Valley and part of the Gulf drainage of the Piedmont. The mountain streams in the Great Smokies are not favorable to this group of reptiles.

Biotic Relationships

Cain (1930) in dealing with the floristic affinities of the trees and shrubs of the Great Smoky Mountains and eastern Tennessee divided the species into two groups, Intraneous and Extraneous. The Intraneous group includes the species which are not near the limits of their distribution and are wholly indigeneous to the region. The Extraneous group includes the species which are locally near the limits of their distribution. Several sub-groups are recognized under each main group. It was found possible to use the same scheme of classification, with modifications, to show the affinities of the amphibian and reptile populations. A lack of distribution data may in a few cases result in a species being put in the wrong classification, but an effort has been made to assign the species as accurately as possible. Table 1 contains a summary of the following list:

Geographic Affinities of the Amphibian and Reptile Fauna of the Great Smoky Mountains

I. Intraneous. (Species not near the limits of their distribution).

Table 1. Summary of Geographical Affinities of the Amphibians and Reptiles of Great Smoky Mountains National Park. This table summarizes the general distribution given in the text.

Authorities for the distribution indicated are principally Stejneger and Barbour, "Check List of North American Amphibians and Reptiles," 1933 edition; Wright and Wright (1933), "Handbook of Frogs and Toads"; Dunn (1926), "Salamanders of the Family Plethodontidae"; Blanchard (1924), "Key to the Snakes of the United States, Canada and Lower California"; as well as my own observations and general reading over a number of years. Assignments are as accurate as present information allows. For discussion of the relationships see the text. The Classification is patterned after Cain (1930) with necessary modifications. Percentages are figured to the nearest .1 per cent.

TABLE 1

Geographical Areas	All Amphibians	Percentages	Salamanders	Percentages	All Reptiles	Percentages	Snakes	Percentages	All Species	Percentages
I. Intraneous	28	77.7	18	72	23	67.6	14	66.7	51	72.8
A. Eastern United States	16	44.4	7	28	14	41.2	9	42.9	30	42.8
B. Southeastern United States	2	5.5	1	4	9	26.4	5	23.8	11	15.7
C. Southern Appalachians	10	27.7	10	40					10	14.3
II. Extraneous	8	22.2	7	28	11	32.3	7	33.3	19	27.1
A. Northeastern United States	3	8.3	2	8	3	8.8	3	14.3	6	8.6
B. Southeastern Piedmont and Coastal Plain	2	5.5	2	8	3	8.8	1	4.8	5	7.1
C. Mississippi Valley	3	8.3	3	12	2	5.9	1	4.8	5	7.1
D. Eastern Seaboard, east of the Appalachian Divide					3	8.8	2	9.5	3	4.3
Totals	36		25		34		21		70	

A. Species widespread over eastern United States, except in some cases absent from (1) Coastal Plain south of Virginia, (2) the highest Appalachians, and (3) New England.

AMPHIBIANS

Triturus viridescens viridescens (Rafinesque)
Ambystoma maculatum (Shaw)
Ambystoma opacum (Gravenhorst)
Plethodon cinereus (Green)
Plethodon glutinosus (Green)
Pseudotriton montanus montanus (Baird) (Largely central)
Desmognathus fuscus fuscus (Rafinesque)
Bufo americanus americanus Holbrook
Bufo fowleri Hinckley
Hyla crucifer Wied
Hyla versicolor versicolor (LeConte)
Rana catesbeiana Shaw
Rana clamitans Latreille
Rana palustris LeConte
Rana pipiens Schreber
Rana sylvatica sylvatica LeConte

REPTILES

Sceloporus undulatus (Latreille)
Cnemidophorus sexlineatus sexlineatus (Linnaeus)
Eumeces fasciatus (Linnaeus)
Heterodon contortrix (Linnaeus)
Coluber constrictor constrictor (Linnaeus)
Lampropeltis triangulum triangulum (Lacépède)
Natrix septemvittata (Say)
Natrix sipedon sipedon (Linnaeus)
Storeria dekayi (Holbrook)
Storeria occipito-maculata (Storer)
Thamnophis sirtalis sirtalis (Linnaeus)
Crotalus horridus horridus (Linnaeus)
Chelydra serpentina (Linnaeus)
Terrapene carolina (Linnaeus)

B. Species occurring over southeastern United States, including the Coastal Plain, Piedmont, and usually the lower Mississippi Valley.

AMPHIBIANS

Eurycea guttolineata (Holbrook)
Gastrophryne carolinensis (Holbrook)

REPTILES

Leiolopisma unicolor (Harlan)
Eumeces laticeps Schneider
Opheodrys aestivus (Linnaeus)
Elaphe guttata (Linnaeus)
Cemophora coccinea (Blumenbach)
Virginia valeriae valeriae Baird and Girard
Tantilla coronata Baird and Girard
Sternotherus minor (Agassiz)

C. Species occurring in the Southern Appalachians, including the Blue Ridge, the Cumberland Plateau and Cumberland Mountains.

AMPHIBIANS

Plethodon jordani Blatchley
Plethodon metcalfi Brimley
Gyrinophilus dainelsi danielsi Blatchley
Pseudotriton ruber schencki (Brimley)
Eurycea bislineata wilderae Dunn
Aneides aeneus (Cope)
Desmognathus fuscus carolinensis (Dunn)
Desmognathus phoca (Matthes)
Desmognathus quadra-maculatus (Holbrook)
Desmognathus wrighti King

II. EXTRANEOUS. (Species near the margin of their distribution).

A. Species occurring principally in northeastern United States.

AMPHIBIANS

Cryptobranchus alleganiensis (Daudin)
Eurycea longicauda (Green)
Pseudacris nigrita feriarum (Baird)

REPTILES

Diadophis punctatus edwardsii (Merrem)
Elaphe obsoleta obsoleta (Say)
Agkistrodon mokasen cupreus (Rafinesque)

B. Species occurring principally in the Piedmont and Coastal Plain of southeastern United States.

AMPHIBIANS

Necturus maculosus x *alabamensis* (Viosca)
Eurycea bislineata x *cirrigera* (Green)

REPTILES

Anolis carolinensis Voight
Eumeces inexpectatus Taylor
Lampropeltis elapsoides virginiana Blanchard

C. Species occurring principally in the Mississippi Valley.

AMPHIBIANS

Plethodon dorsalis (Cope)
Gyrinophilus danielsi x *duryi* (Weller)
Eurycea lucifuga Rafinesque

REPTILES

Lampropeltis getulus nigra (Yarrow)
Amyda spinifera (Le Sueur)

D. Species occurring principally on the eastern seaboard, west to the crest of the Appalachians, and beyond in the Southern Appalachians.

REPTILES

Carphophis amoena amoena (Say)
Lampropeltis getulus getulus (Linnaeus)
Chrysemys picta picta (Schneider)

TABLE 2. Geographic affinities of the native trees and tree-like shrubs known to occur at Great Smoky Mountains National Park. The list of trees (not reproduced here) is from unpublished data made available to my by Dr. H. M. Jennison, formerly Associate Botanist, National Park Service. The distribution of the several species is taken from the standard manuals, namely: Coker and Toten (1934), "Trees of the Southeastern States"; Gray's New Manual of Botany (Seventh Edition); Sargent (1933), "Manual of the Trees of North America"; Small (1933), "Manual of the Southeastern Flora"; Sudworth (1927), "Check List of the Forest Trees of United States."

Geographic Areas	No. of species	Pct. of the total
I. INTRANEOUS SPECIES	92	73.6
A. Entire eastern United States except the southern Coastal Plain in some instances	43	34.4
B. Central portion of eastern United States	12	9.6
C. Southeastern United States	19	15.2
D. Entire Appalachian Area	6	4.8
E. Southern Appalachian Area	12	9.6
II. EXTRANEOUS SPECIES	29	23.2
A. Canadian	5	4.0
B. Northeastern United States	17	13.6
C. Southeastern Piedmont and Coastal Plain	3	2.4
D. Mississippi Valley	4	3.2
III. UNCLASSIFIED SPECIES	4	3.2
Totals	125	100

A recent unpublished list of the native trees and tree-like shrubs known to occur at Great Smoky Mountains National Park, includes 125 species. This list of plants was made available to the writer by Dr. H. M. Jennison, formerly Associate Botanist, National Park Service, for the purposes of comparing the geographic affinities shown by the amphibians and reptiles with those indicated by the native trees. Table 2 presents this information for 125 species of plants and enables a close comparison with Table 1. It will be noted that a few of the sub-groups are not comparable, the principal difference being that the amphibians and reptiles are not represented by a Canadian element, but do include a few species restricted largely to the Atlantic Coastal drainage. This last province is not represented in the floral table.

In comparing Tables 1 and 2 many striking similarities in composition of fauna and flora are brought out. All Intraneous species make up 73.6 per cent of the plants and 72.8 per cent of the animals. This similarity in composition presents an interesting correlation. Of especial note is the preponderance of species that are widespread in eastern United States (including Plant sub-groups IA and B). Southeastern forms rank second (both Intraneous and Extraneous Groups) with 17.6 per cent of the trees and tree-like shrubs (including sub-groups IC and IIC) and 22.8 per cent of the amphibians and reptiles. The relatively small influence of the typically far southern species of trees and shrubs, estimated by Cain at less than 6 per cent, is well balanced by the Extraneous southern species of amphibians and reptiles, in per cent, 7.1. Cain's explanation "The extent and high altitude of the Southern Appalachians (culminating in the Great Smoky Mountains) accounts for the relative absence of southern forms because of the actual scarcity of climatic and edaphic

situations suitable for such a flora" summarizes the underlying causes. Southern Appalachian trees and tree-like shrubs make up 9.6 per cent of the total in Table 2, while in Table 1, all the strictly Southern Appalachian species encountered are salamanders, and constitute 14.3 per cent of all species, 27.7 per cent of the amphibians, and 40 per cent of all salamanders. The failure of these endemic species to spread more widely seems explained by the absence of suitable habitat elsewhere. Their abundance here is undoubtely due to the ancient geologic age of the Great Smoky Mountains and southern Blue Ridge.

Influence of Geology and Physiography

The Great Smoky Mountains are not only the single largest mountain mass in eastern United States, but are among the oldest. The Southern Appalachians are thought to have arisen as a result of diastropic movements, including uplifting and pronounced horizontal thrust, toward the close of the Paleozoic Era. Although the area was peneplaned during the Mesozoic, further uplift occurred in the Cretaceous Period and again in the Pleistocene. Erosion occurred in the interims and is still in operation. The mountainous area has held its character as an uneven land mass since the Paleozoic, never having been entirely inundated since that time. The rocks of the Great Smokies are consequently old, and the greater portion of the park is covered by Cambrian sediments in various stages of metamorphism. A relatively small body of Pre-Cambrian granite and gneiss is found on the Qualla Indian Reservation and the area immediately north of it in the park along Raven Fork. Limestones of Ordovician Age are found in the western end of the Great Smokies and exercise some influence on the faunal populations. The Cambrian rocks are principally of slate, shale, sandstone, graywacke and conglomerate. The conglomerates are especially massive and cap most of the higher peaks. The decomposition of these rocks results in soil which is usually on the acid side of neutrality. Only in the relatively small flat areas of the coves at low elevations is the soil of any great depth.

Cades Cove, lying in the western end of the park is exceptionally interesting, both from the standpoint of its geology and its fauna. The Cove consists of approximately 2,500 acres of flat or gently rolling land, surrounded by mountains. The flat land has been in cultivation for almost a hundred years. The Cove is regarded as a fenster in the Knox Dolomite Formation of Ordovician Period. The limestone has been worn away by surface and underground waters, so that the Formation is largely gone, leaving the attractive valley. The presence of the limestone which is more recent than the Cambrian rocks has enabled a few animals not found elsewhere in the park, to penetrate into the Cades Cove area. The following should be mentioned in this connection:

Eurycea lucifuga	*Chrysemys picta picta*
Gastrophryne carolinensis	*Cemophora coccinea*
	Natrix septemvittata

The last three species are not restricted to limestone areas outside the park, so their presence here should be attributed at least in part to the comparatively

Fig. 1. A view of Cades Cove, showing the variety of habitat afforded by cultivated and abandoned fields, wooded slopes, and meandering streams. The Cove is considered a fenster in the Knox dolomite, and has reached a stable level, ranging from 1700 to 1800 feet in elevation. Photograph taken September 1, 1936, by Dr. H. M. Jennison.

lower elevations obtaining in the Cades Cove area, and the occurrence of suitable habitat not necessarily requiring limestone strata as a base.

The Great Smokies constitute a physiographic unit, and should be considered as one faunal or floral area. Too frequently faunal reports deal with artificial boundaries and exaggerate the importance of state boundary lines. In this paper the state is given in connection with locality records only when the collection was made near a village or in a geographically recognized area outside the park, or when two related subspecies of a form are known to occupy opposite sides of the North Carolina-Tennessee State Line. This type of distribution is known only for the chain snake, *Lampropeltis getulus*.

No more scenic or rugged area occurs in eastern United States than the Great Smokies. Along the State Lise, an elevation of more than 5,000 feet is maintained for more than 36 consecutive miles. There are 16 peaks whose summits are more than 6,000 feet in elevation. The break from the top is rapid, especially so on the north side of the park. At elevations of 5,000 feet

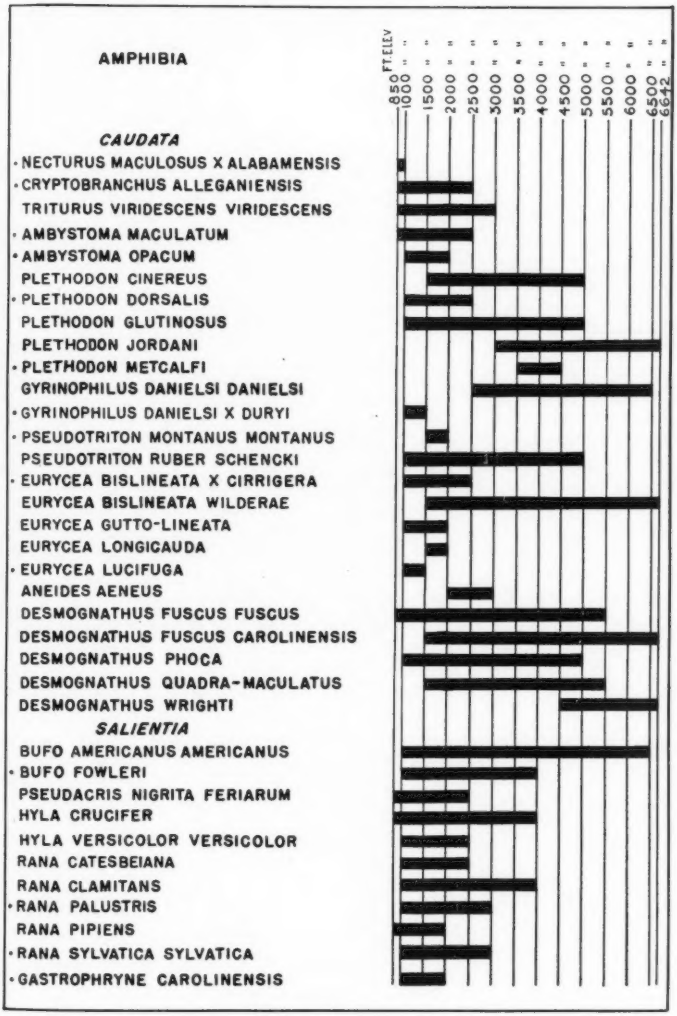


Fig. 2. A list of the amphibians of Great Smoky Mountains National Park, with the elevations which each is known to occupy. The lowest point in the park, the mouth of Abrams Creek, is 850 feet elevation. The highest is to the top of Clingmans Dome, 6,642 feet. If a species is known to enter any band of 500 feet, it is given as occurring throughout that band. If a species has been taken approximately on the border between two bands, it is listed as occurring in both the one above and the one below. Species marked with a dot (·) are herein reported from the Great Smokies for the first time.

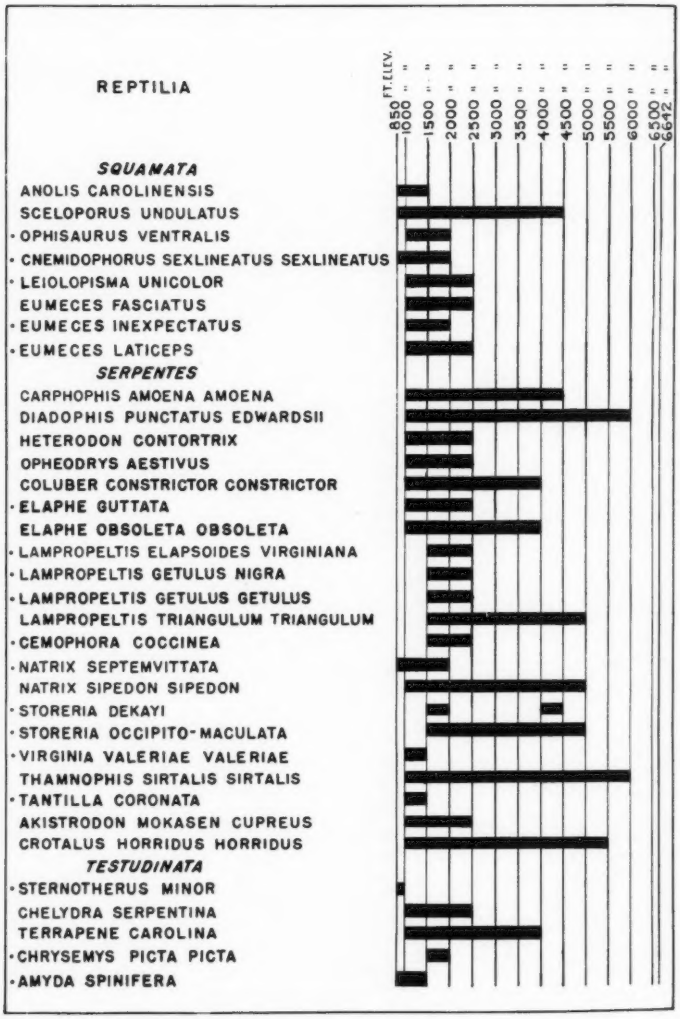


Fig. 3. A list of the reptiles of Great Smoky Mountains National Park, with the elevations which each is known to occupy. The interpretation is the same as for Fig. 2.

to 1,500 feet on that side, the gradient on the principal streams averages close to 8 per cent. On the North Carolina side the average elevations are higher and the streams descend more slowly, especially below 4,000 feet. The gradient here will run from 4 to 6 per cent on the average. The streams have been the paths of migration for many of the amphibians, especially the salamanders. Their rugged character, clear cold water, and sheer beauty are well known.

Figures 2 and 3 give the distribution of amphibian and reptile species according to elevation. Collection records show that 20 amphibians and 22 reptiles have not been found above 3,000 feeet which is approximately the mid-point in elevation represented. On the contrary only 4 salamanders and 1 snake (a melanistic phase of the garter snake, *Thamnophis sirtalis*) are restricted to elevations above 3,000 feet. There is a definite falling off of species around 2,500 feet, which marks about the upper limit of what is considered the Upper Austral Zone. A second break occurs at from 4,000 to 5,000 feet. This marks the average maximum elevation for the western half of the park and in the eastern portion the border of the spruce-fir forest. The effect of the forest types on faunal distribution is discussed later in this paper. In connection with the above, it is interesting to note that only 7 salamanders, 1 toad, and 2 snakes are known to occur normally above 5,000 feet. The limiting factors in the vertical distribution are probably only secondarily the effect of altitude. The requirement for occurrence at any elevation is suitable habitat, which in turn depends on the nature of the rock and earth, and even more upon proper water conditions and the plant community.

Influence of Climate on Fauna

The Great Smoky Mountains have no single climate. At the lowest elevations, light, temperature and moisture conditions are comparable to those in the vicinity of Sevierville, Tennessee, or Bryson City, North Carolina. On the high mountains such as Clingmans Dome, Guyot and LeConte entirely different conditions prevail. Partial weather data has been kept for a period of years at Gatlinburg, Elkmont, and Bryson City, but the data is very meager for the high mountains. The effect of the great variation in climate from the lowest to the highest elevations most certainly affects the animal populations. Spring comes from two weeks to a month later at 6,000 feet than it does at 1,500 elevation. This can be readily seen in the blooming period in the same species of such plants as *Claytonia virginica, Houstonia caerulea, Azalea calendulacea, Halesia carolina*, and others that transcends the elevations afforded by the Great Smokies.

Elkmont, located near the center of the park at 2,150 feet elevation, offers conditions more nearly average than any other weather station in or near the park. Climatological records over a ten year period (1927, 1929-1937) show an average annual precipitation of 65.5 inches and an average mean temperature of 55.8 degrees Fahrenheit. Humidity and light readings are not available. The lowest winter temperatures are about zero and the highest summer readings reach 95 to 100 degrees Fahrenheit.

The Tennessee Valley Authority now has rain gauges placed at several

places in the upper Tennessee Valley, including one on Clingmans Dome. Precipitation data are available from the last locality only for 1936 and 1937. During these two years the rainfall was 87.5 and 88.5 inches respectively. At Elkmont during the same years, the precipitation was 56.3 and 55.5 inches. For further comparison the rainfall at Knoxville was 48.6 and 50.3 inches during the same years. The horizontal distance from Clingmans Dome to Elkmont is not more than 8 miles, while Knoxville is more than 30 miles in a direct line northwest from Elkmont. Two years are too brief a period to make any conclusive comparisons, but do not indicate that the rainfall on the higher peaks may be as great as 80 to 90 inches annually. In a few years further quantitative data will be available.

The nature of the spring controls the time of emergence and the beginning of breeding activities for the amphibians and reptiles. Dates are given for several of the species listed under the species descriptions. The season varies considerably and an average date which a species may be expected to make its appearance or lay its eggs can hardly be determined. The same is true of the fall hibernation. Frequently some of the more common snakes are seen on sunny days in November. Undoubtedly climate either directly or indirectly through its influence on the growth of vegetation, plays a large part in determining the occurrence and distribution of many of the amphibians and reptiles found locally.

Influence of Vegetation on Faunal Distribution

The abundant and highly varied flora of the Great Smoky Mountains has been commented upon by practically every botanist who has visited the area (Galyon, 1928). Probably the Great Smokies will continue to be known for its plant life more for any other single feature. At least 125 species of native trees and tree-like shrubs occur within its boundaries. About 40 per cent (38 to 40) of the forest cover types recognized for eastern United States are represented (see ref. cited). The number of herbacous plants, shrubs and vines is still in the speculative stage, but is indeed impressive. The effect of the wide variation in forest types and ground cover on the faunal populations naturally is great. The total acreage shown within the park boundary is approximately 440,000 acres and at least half of this total area is in virgin forest and will remain so. Most of the cut-over areas are revegetating rapidly under the protection afforded by the National Park Service.

The importance of vegetation in regulating the environment and thereby creating varied faunal habitats can scarcely be overestimated. The presence of the spruce-fir forests on the high peaks and ridges in the eastern three-fifths of the Great Smokies marks an environment not only highly characteristic in climate and soil, but in the composition of groundstory plants. The following species are typical of this habitat:

Plethodon jordani
Desmognathus fuscus carolinensis
Desmognathus wrighti
Thamnophis sirtalis sirtalis (melanistic phase)

Forests at this elevation are cold and wet. The surface of the ground rarely becomes dry, and a heavy protective layer of moss and ferns not only conserves the moisture but offers the type of habitat desired by the salamanders noted above.

Perhaps the second most distinctive correlation exists between the animals and plants in the pine-oak-heath complex at elevations below 3,000 feet. This type of forest is warm, dry and light. There is considerable ground cover, but it is easily penetrated. Species most commonly associated with this habitat include:

Plethodon glutinosus
Liolopisma unicolor
Anolis carolinensis
Eumeces laticeps
Opheodrys aestivus
Cemophora coccinea
Virginia valeriae valeriae
Tantilla coronata
Crotalus horridus horridus
Terrapene carolina

Other groups of species might be listed which occupy principally the moist valleys along streams, or the open forested slopes of the coves. However, these lists cannot be clear cut and need not be given here because habitat preferences are indicated whenever possible in the separate species accounts. It is interesting to note that the abundance of decaying logs, often moss covered, influences to a large degree the relative abundance of many of the forms, especially the salamanders. The practice of felling and flattening dead trees as a fire hazard reduction measure, so popular in parks and forests during recent years, probably has favored the salamanders, lizards and snakes, but has been unfavorable for many kinds of birds. Certainly there is still an abundance of dead wood in the Great Smokies, both felled and standing. The collector soon recognizes that some of the plant communities offer undesirable habitat for amphibians and reptiles. Principal among these are the heath balds or slicks. These are practically impenetrable and have a heavy layer of peat over an extremely acid soil. Frequently the hardest places to collect yield the poorest results, both in species and individuals.

Disturbance of the original vegetative cover seems in general to be adverse to the salamanders and beneficial to the snakes. Clearings attract birds, mammals and insects, which furnish food for the snakes, but admit light which dries out the soil and makes conditions unfavorable for the moist skinned amphibians. In logged-over areas, the amphibians and reptile forms will usually persist, even with reduced numbers, unless fire follows the logging to complete the devastation. Almost invariably success in collecting specimens of salamanders declines in an area for a period of years following logging. Streams which harbored good populations of such species as *Desmognathus quadra-maculatus* become poor hunting grounds for the herpetologist. At low elevations the effects of logging on the fauna are not so pronounced.

Systematic Treatment

In the succeeding pages of this report, the status and known distribution of each species reported from the Great Smoky Mountains National Park is given.

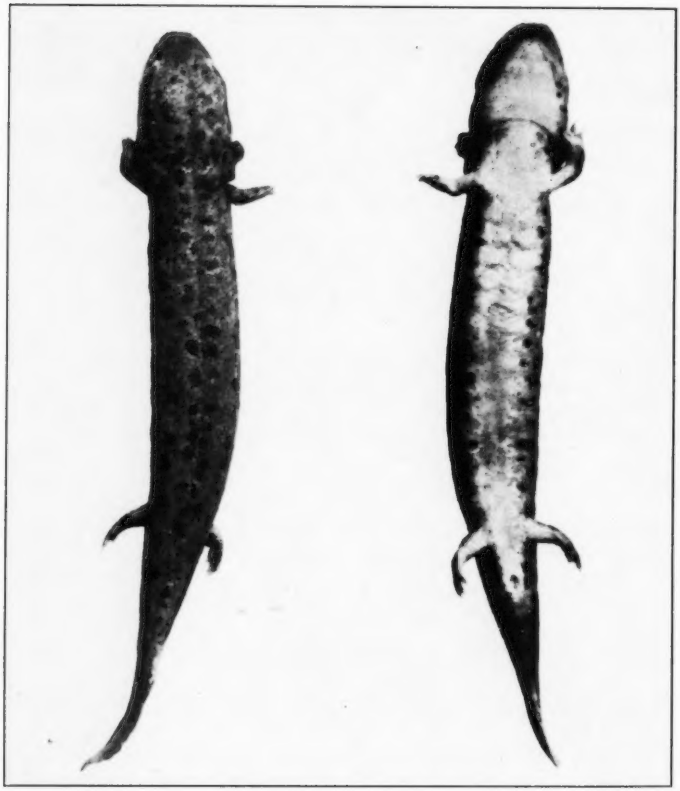


Fig. 4. Dorsal and ventral views of *Necturus maculosus* x *alabamensis*. This animal, an adult female measuring 229 mm., in total length was taken from the Clinch River at Norris, Tennessee. Note the unpigmented venter and the tendency for the dorsal spotting to fall into rows.

CAUDATA

Necturus maculosus x alabamensis (Viosca)

Two adults and several larvae of a mudpuppy were taken by Dr. Carl Hubbs and the writer from Abrams Creek, just above its junction with the Little Tennessee River, on September 6, 1937. We were seining for fish and were fortunate in obtaining the salamander. The stream is quite clear, and has only a moderate current. The stream bed has many projecting rock ledges and large flat stones which offer suitable habitat for the salamander. Mudpuppies have not been taken elsewhere in the park.

Since this manuscript was submitted, the writer has had opportunity to examine briefly Mr. Viosca's collection of mudpuppies, including the new species, *Necturus louisianensis*. It appears that there is a closer similarity in both adults and larvae between the form from the upper Tennessee drainage and the one from central Louisiana than there is between it and *N. alabamensis*, described by Viosca in 1937. The relationships of *N. alabamensis* to *N. louisianensis* and to *N. maculosus* have not been worked out and the writer hesitates to confuse the picture further by adding another name at this time. The mudpuppies from the upper Tennessee doubtless are different by at least subspecific rank from *N. maculosus* of the Ohio and upper Mississippi Valleys, and approach the more southern forms in many characters.

Dr. A. R. Cahn has contributed several specimens of *Necturus maculosus* from the Clinch River, taken just below Norris Dam. I have examined these animals closely and they are the same as those from Abrams Creek. A table of measurements of specimens from Abrams Creek and the Clinch River is given for purposes of reference (see Table 3).

A description of the animal in life, based on 3 specimens from Norris, follows. The color is dark amber, russet brown or brownish gray, grayer on the sides and lighter ventro-laterally. The dorsum is flecked with small white or yellow spots which disappear in formalin. Black spots, more or less arranged in rows are prominent. The dorso-lateral rows contain the largest spots, which are in the region of the groin and the proximal two-thirds of the

TABLE 3. Measurements of 5 specimens of *Necturus maculosus* from the Clinch River at Norris, Tenn., and 2 from Abrams Creek in Great Smoky Mountains National Park. The number of teeth is half the number present on both sides. I am indebted to Mrs. Helen T. Gaige for the loan of the three specimens from the University of Michigan Museums, to Dr. A. R. Cahn of the Tennessee Valley Authority for obtaining live *Necturus* for me, and to Dr. Carl L. Hubbs for his part in helping collect the specimens from the Great Smoky Mountains.

	T.V.A. Coll., Clinch River		Univ. of Mich. Coll., No. 82957 Clinch River			G.S.M.N.P. Abrams Creek		
Sex	Female	Female	Female	Female	Male	Female	Female	Averages
Total length	218	229	227	225	213	240	216	224
Length of head	33	37	38	39	37	42	38	36.6
Length of body	118	124	117	116	111	124	109	117
Length of tail	67	68	72	70	65	74	69	69.3
Head and body	151	161	155	155	148	166	147	154.7
Width of head	24	26	28	28	25	28	25	26.3
Depth of head	14	15	16	15	16	17.5	16	15.6
Head length in body length	3.6	3.4	3.1	3.0	3.0	3.0	2.9	3.1
Head width in head and body length	6.3	6.2	5.5	5.5	5.9	6.1	5.9	5.9
Body width	25	26	26	26	22	23	22	22.9
Body depth	17	19	23	22	22	18	15	19.4
Body width in body length	4.7	4.8	4.5	4.5	5.0	5.4	5	4.8
Body depth in body length	6.9	6.5	5.1	5.3	5.0	6.9	7.3	6.1
Premaxillary teeth	..	9	8.5	9	8.5	8	8	8.5
Vomero-palatine teeth	8	11	13.5	11	11	12	10.5	11
Pterygoid teeth	5.5	5.5	7	6	5	5.5	6	5.8

tail. The median rows of spots (usually 2 rows visible) are smaller, and may unite at the base of the tail or extend on to the tail, bordering its dorsal edge. The longitudinal rows of spots loose their identity in irregular spotting on the head. The pigmentation on the sides is somewhat more irregular, and the spotting is only indefinitely arranged in two longitudinal rows. The zone between the pigmented sides and the unpigmented venter varies with individuals and with age, but all specimens examined have a plain median band from neck to anus. The muzle is obtusely rounded to slightly truncate. A dark line on the canthus etxends from the area about the nostril through the eye to the base of the gills. The muzzle and forehead are decidedly flattened. The form is on the whole, smaller, slenderer, more flattened, has a more primitive pigment pattern, a somewhat larger eye and a reduced number of teeth, in comparison with typical *N. maculosus*.

Six larvae taken from Abrams Creek, with the adults mentioned above, are from 35 to 37 mm. in total length. These show three dark brownish stripes, one on the dorsum and one on either side. The median stripe widens on the head and narrows to a blunt point on the muzzle. The lateral stripes occupy approximately two-thirds of the lateral body surface, and extend beyond the gills to the eye and more narrowly to the tip of the snout. Separting the dark bands are creamy white stripes, which unite on the snout and extend in broken fashion on to the tail. The upper parts of the limbs are dark and the under parts, together with the venter, are creamy white.

The fauna of the Alabama drainage system is in general different from that of the Tennessee, but some species of aquatic cold blooded vertebrates are known to occur in both. Dr. Hubbs has found such a relationship in fishes (unpublished data), and the small mud turtle, *Sternotherus minor*, a companion species to the Tennessee *Necturus*, also occurs in the more southern drainage in Alabama (Stejneger and Barbour, 1933). The possible effects of earlier stream piracy, and the changes in drainage even prior to Recent Time are interesting phases of the distribution problem and deserve further study in southeastern United States. Both the mudpuppy and the mud-turtle are "old" species and may well antedate the present drainage systems.

Cryptobranchus alleganiensis (Daudin)

This, the largest of the American salamanders, occurs in the larger streams of the Great Smokies. Specimens have been taken in Little River near Elkmont at 2,200 feet elevation, in the West Prong of Little Pigeon River near Gatlinburg and in Abrams Creek at 900 feet elevation. The species has been observed in the Middle Prong Little Pigeon below Greenbrier and in Hazel Creek and Deep Creek in North Carolina. It probably occurs in most of the larger streams of the park below 2,500 feet elevation.

A female specimen taken at Elkmont, August 28, 1936, contained ripened eggs. A male taken two days earlier regurgitated a mass of the eggs of the species when it was chloroformed. At this season males may be readily distinguished from females. In males the region about the vent is greatly swollen and a marginal row of enlarged tubercles encircles it. Males also show more

expansive folds of skin on the toes and a larger fold on the outside of the lower leg and upper tarsus regions than do females. The head is somewhat broader and heavier in appearance in the male. Skin on the lateral portions of the body also seems more convoluted. The largest specimen in the collection, a male No. Ca-4 collected in the Little Pigeon River near Gatlinburg September 2, 1936, by Donald Payne, measures 686 mm. in total length. The head is 88 mm. wide at the widest point and 30 mm. thick at the posterior angle of the mouth. The tail including the dorsal skin fold is 80 mm. high, 262 mm. long, with the skin fold greatly convoluted. A female, No. Ca-3, collected at Elkmont by Ralph Proffitt, August 28, referred to above, is 635 mm. long; the head is 72 mm. wide at the widest point and 29 mm. thick at the posterior angle of the mouth. Its tail is 55 mm. high, 233 mm. long, with the skin fold smooth and only slightly convoluted.

The importance of this species in the economy of the stream is not well understood, especially in this section of its range. It is unlikely that it competes severely with other species such as rainbow trout. It does not appear to be abundant in park streams.

Triturus viridescens viridescens (Rafinesque)

The scarcity of ponds in the mountain area limits the distribution of this species. Wherever a natural or artificial pond does occur, or in pockets caused by a stream overflowing, newts are almost certain to be found. Courtship behavior has been observed most commonly in March but records of mating activity have been reported as early as January 15. The species is very common in the Cades Cove area, where several sink-holes and marshy spots occur. It has also been taken on Laurel Creek, at the Sinks on Little River, near Gatlinburg, at Elkmont, Chilhowee and Greenbrier. The red eft stage is frequently found on wet trails or under logs on ridges several hundred yards from any permanent water.

Ambystoma maculatum (Shaw)

The spotted salamander is found in habitats similar to those where the common newt occurs, but is more limited both as to numbers and localities. The species has been observed in Cades Cove, at the Sinks on Little River, Laurel Creek sink holes, Gatlinburg, the Sugarlands area and at Elkmont. It doubtless occurs at several other localities within the park. In general the distribution is scattered, in pools and sink holes below 2,000 feet elevation. Adults are rarely collected or seen except during the short breeding period.

The species usually follows the wood frog *(Rana sylvatica sylvatica)* closely in its spring emergence, and begins breeding activity often before the ice is all out of the ground. The breeding season at this latitude naturally is quite variable. The usual procedure is that a period of warm weather in late January or early February brings out some of the animals and a few egg masses result. Unless the warm weather continues for a week or longer, the principal breeding season is postponed until such a season does arrive.

In 1935, the first egg mass was seen January 17 along Dudley Creek near

Gatlinburg, although the peak of egg laying was not reached until a month later. In 1936, the first eggs were found February 24 in the Sugarlands area. In 1937, the first eggs were laid in the pool at the Sinks on Little River January 15, and several warm days brought the activity to completion. Adults were seen in a small pond at Elkmont January 23, 1938, and eggs were laid on January 30, while at the Sinks on Little River *A. maculatum* laid its eggs the week of February 6 to 12. In the last location, I have counted as many as 95 egg masses of this species in a pool not over 20 feet in diameter.

Ambystoma opacum Gravenhorst

Adults of the marbled salaamnder escaped capture in the Great Smokies until October 5, 1938, when Mr. Authur Stupka, Park Naturalist, found the first specimens along the margin of a dried-up pond in the upper end of Cades Cove. Two females both brooding nests of eggs were found under old boards. On October 14, I found the species common in the sweet gum-buttonbush-red maple swamp at the lower end of the Cove (see Fig. 9). Seven females were found, with their bodies resting directly on the eggs. Six of these contained 172, 141, 117, 106, 146, and 99 eggs, respectively, or an average of 130 eggs each. They were under logs, in places which are covered by water in the winter and spring, but which at the time the collections were made, were dry.

On October 16, 1938, adults of *A. opacum* were found in three of the sink holes on Laurel Creek. All of the nests found were under logs or rocks. In southwestern Ohio, where I have also found the species breeding, the nests are usually under leaf litter in pockets or tunnels made by rodents, but otherwise their habits in general appear similar (King, 1935). *Ambystoma* larvae were found in a pool along Dudley Creek near Gatlinburg, on June 6, 1934, and tentatively identified as *A. opacum*. *A maculatum* larvae were also present and could be readily distinguished by their smaller size alone. Adults of the marbled salamander have not been reported from the vicinity of Gatlinburg, but probably occur there.

Plethodon cinereus (Green)

The red-backed salamander is an uncommon species in the Great Smokies and appears to occupy a slightly different position than does the closely related species *P. dorsalis*. All our collections have been made from pine-oak or mixed hardwood forests between 1,500 and 5,000 feet elevation. The species seems to prefer slopes having fairly dry soil. On the other hand, *P. dorsalis* seems to occupy the flatter moister areas at lower elevations. The two species are also readily distinguished by the greater pigmentation of the belly in *P. cinereus*, the relative length of the tail which equals or exceeds the head and body, and the larger number of costal grooves (18 to 20 in this species). *P. dorsalis* on the other hand has the belly lighter, tail not exceeding the head and body in length, and usually 16 to 18 costal grooves.

Park records are scattered from White Rock in the east to Forge Creek in the west end of the park, including stations at Trillium Gap on Brushy

Lead, the Newfound Gap Highway, Elkmont, the Sinks on Little River and White Oak Sinks. Weller (1931) records the species from the slopes of Mount LeConte. Inasmuch as he states the specimens are of the red-backed phase and have 21 costal grooves it is likely that they are of this species.

Plethodon dorsalis (Cope)

Early collections of this species were confused with those of *P. cinereus*. The differences are outlined under the description of that species. *P. dorsalis* also appears slightly more robust.

An old sawmill site on the floor of White Oak Sinks yielded 24 specimens in an hour's collecting, March 22, 1935. The animals were found under practically every old board and slab and occasionally under flat stones and logs. The species is common along the bases of the ridges between Gatlinburg and the Sugarlands area. Park collections from the above localities and from Dudley Creek and Dry Valley on the Tennessee side of the park were taken at elevations from 1,300 to 2,000 feet. The species has not yet been taken on the North Carolina side of the park, but may occur there, most likely toward either end.

Plethodon glutinosus (Green)

Plethodon glutinosus is common and widespread in the Great Smokies, up to as great an elevation as 5,000 feet. It does not appear to enter the spruce-fir forest to any great extent and is most common on oak and pine clad ridges at moderate elevations. The collection at Great Smoky Mountains National Park includes specimens taken from 20 localities well distributed over the entire park area. Occasional specimens have the white mottling reduced or nearly absent, but a careful examination leaves no doubt as to the identity of the form. On the high hardwood ridges running off from Gregory Bald, Thunderhead and other peaks in the west end of the park, the species is frequently encountered in company with *P. jordani*. There is no evidence of intergradation.

Plethodon jordani (Blatchley)

Probably more herpetologists search for this species in the Great Smokies than for any other kind of salaamnder. It is very common and widely distributed above 4,000 feet elevation, but has been taken on Indian Creek, North Carolina, and Ramsey Prong, Tennessee, as low as 3,100 feet. It is most abundant in the red spruce-Fraser's fir forest and is also found on the hardwood covered ridges in the west end of the park at suitable elevations. The park collection contains specimens from at least 20 different localities, and the species has been seen but not collected in at least that many more places.

The cheek patches are usually well developed rosy-red, but occasional specimens have an orange or even yellow cast. In relatively few individuals the red pigment is poorly developed, and I have seen only two in several hundred live and preserved specimens that showed no trace of red, orange or yellow on the cheek patches.

Fig. 5. The headwaters of the Road Prong of the West Prong, Little Pigeon River. The locaton shown is just below Indian Gap at 5,000 feet elevation and is the type locality for *Plethodon jordani* and *Cyrinophilus dainelsi danielsi*. *Desmognathus fuscus fuscus*, *Desmognathus fuscus carolinensis*, *Desmognathus quadra-maculatus*, *Desmognathus wrighti*, and *Eurycea bislineata wilderae* are present in the same locality.

No one has yet succeeded in finding the eggs of this species. The forest floor where the species is most abundant consists of a heavy layer of moss with only a little soil over rock. This rock usually is a mass of boulders of such proportions that collecting below the surface becomes a well nigh impossible feat.

Measurements and study of a series of 67 entire individuals shows a size range of 43 to 149 mm. total length. The animals group themselves logically into two groups, one ranging from 43 to 63 mm. and the other 80 to 149 mm. It is likely that the first contains individuals in their second year of growth, while the second group contains specimens in their third and subsequent years of growth. There is some indication of a break between 98 and 104 mm. but I have not measured enough specimens to determine whether or not this holds true in a large series. Apparently the animals do not reach sexual maturity before their third summer or a size of 80 mm. Small individuals, between 30 and 40 mm. have been noted in nature, in April and May. Frequently individuals are taken which are in the process of devouring small snails, beetle larvae and other insects. The mucous from this species is extremely viscous and is removed from the human skin with difficulty.

Plethodon metcalfi Brimley

The presence of this species in the Great Smokies comes as a surprise to most herpetologists. Stejneger and Barbour in their Check List (1933) state, "It apparently occupies all the ranges of the Southern Blue Ridge except the Great Smokies and the Nantahalas." This statement is exactly that given by Dunn (1926) in his Monograph of the Family *Plethodontidae*.

The park collection contains a series of 16 specimens of the species ranging from 40 to 120 mm., including individuals of both sexes. The writer collected 15 of these on Hyatt Ridge, on September 12, 1934, at elevations from 3,500 to 4,100 feet. Mr. Raymond Fleetwood, former Resident Wildlife Technician, collected one specimen on Cataloochee Divide at 4,500 feet elevation, June 11, 1935. I have seen and taken the species at Highlands, North Carolina, in numbers, and when the specimens from the two localities are compared, they are identical. *P. jordani* occurs on the same ridges and I have taken it less than a mile from the point where *P. metcalfi* was taken. A comparison of local specimens of the two species leaves no doubt as to their distinctness. *P. metcalfi* is generally less heavily pigmented, especially on the ventral body portions, has one less costal groove (15), and is withal a slimmer and less muscular species. The submental gland on the male is quite highly developed.

Collections were made in oak-chestnut forest, under logs, in areas having relatively good deep soil. The presence of the species on the two ridges in question is not difficult to explain. Balsam Mountain extends from the State Line, the main crest of the Smokies, southward eventually joining the main mass of the Balsam Mountains. It rarely dips below 3,000 feet elevation. The type locality for the species is Sunburst, North Carolina, near the southern end of the Balsam Divide, less than 20 miles from the points of collection in the

park, and in the same county. Extending east from Black Camp Gap on Balsam Mountain is the Cataloochee Divide, all of which is in Haywood County, North Carolina. Hyatt Ridge likewise joins Balsam Mountain before it reaches the State Line. The path of migration has been an easy one. Its presence on Balsam Mountain, Cataloochee Divide, Hyatt Ridge and probably Mt. Sterling Ridge, as well as other tributary ridges is rather to be expected.

Gyrinophilus danielsi danielsi (Blatchley)

This is one of the strikingly colored salamanders of the Great Smokies. The scattered black spots on the deep salmon ground color, together with the broad flat head and prominent canthus rostralis readily distinguish it. It is typically found under the stones and in the soft banks of small streams at elevations above 2,500 feet. Occasionally it is found under stones, logs or moss on ridge tops several hundred feet from any water. The species is seldom numerous in any locality but it widely distributed over the park in suitable elevations and habitats. The collection at Great Smoky Mountains National Park includes specimens from Tricorner Knob, Mount Chapman, Pecks Corner, Laurel Top Mountain, Gregorys Bald and Indian Gap (the type locality) along the State Line, and also from Cataloochee Divide, Mount LeConte, the Chimneys area, and Haw Gap on Jenkin Trail Ridge. Weller (1931) lists a specimen in the Ohio State Museum collection from Gatlinburg. I am familiar with the history of this specimen and know that it was collected by F. O. Hazard of Wilmington, Ohio, on LeConte Creek above Gatlinburg at an elevation of 2,600 feet.

On the night of April 20, 1937, Mrs. King and I were driving from Gatlinburg to Waynesville between 8 and 9 P.M. It was a warm, foggy night, following a period of showers. On the Newfound Gap road, Tennessee side, between 3,500 and 5,000 feet elevation we saw at least 200 salamanders of this species crawling about on the road. They could be seen at considerable distance because of the contrast of their light bodies on the black surface of the road, but even more striking was the reflection from their eyes. The presence of so many of these comparatively uncommon animals made the observation all the more interesting.

Gyrinophilus danielsi x *duryi* (Weller)

The relationships of the three known forms of *Gyrinophilus*, namely *G. porphyriticus* (Green), *G. danielsi* (Blatchley), and *G. duryi* (Weller), have not been clearly known. Stejneger and Barbour in their 1933 edition of the Check List classify all three as subspecies of *G. porphyriticus*. It is the writer's opinion that suffiicent material is at hand to indicate what the relationship actually is, at least in reference to *G. danielsi* and *G. duryi*.

Gyrinophilus danielsi (Blatchley) is a species of the higher mountains, and in the Great Smokies typical specimens have not been taken below 2,500 feet elevation. The T.V.A. collection at Norris contains two *Gyrinophilus* from Great Smoky Mountain Caverns, which are situated in Tuckaleechee Cove at about 1,200 feet elevation. Very recently, I have also obtained two more

Fig. 6. Dorsal and ventral views of *Gyrinophilus danielsi* x *duryi*, from Little River at 1,100 feet elevation. Note the elongate body, comparatively narrow head, and scant ventral pigmentation. The specimen, an adult female, measured 156 mm. in total length.

specimens from Little River, one at 1,100 feet and one at 2,100 feet elevation. These four are alike in body proportions and general appearance. The color in life is salmon-red, more reddish than *G. danielsi* from higher elevations. The pigmentation on the head is decidedly less heavy than the latter form. The canthus rostralis is less pronounced and the snout is decidedly more rounded. The body wall is more translucent and does not become as brown in formalin as does *G. danielsi*. Dorsal spotting is mainly of small black dots which encroach on the ventral portion of the body only in the anterior region. These characters agree quite closely with *G. duryi* as described by Weller (1930). Weller's description of the animal is accepted even though it was

placed in the wrong Genus, namely *Pseudotriton*, at the time. No specimens of the form from Tennessee have been reported, to my knowledge. It is evident that *G. danielsi* and *G. duryi* are very closely related and intergrade in the southern extremities of the Great Smoky Mountains and possibly the Blue Ridge. *G. danielsi* appears the most primitive. The more elongate body of *G. duryi* according to Dunn (1926) would indicate a more recent origin. This fits in well with the geological story. The two animals are so near alike anatomically, that I am reducing them to subspecies under the form first described. They then become *Gyronophilus danielsi danielsi* (Blatchley) and *Gyrinophilus danielsi duryi* (Weller), respectively. Only in this way can the specimens at low elevations in the Great Smoky Mountains be satisfactorily placed.

The first specimen of *G. danielsi* x *duryi* that was taken in the park, was found by a labor crew engaged in cleaning a roadside ditch on Little River. The salamander was running through the shallow muddy water, in the process of swallowing a *Plethodon glutinosus*. The *Gyrinophilus* was 156 mm. long and the *Plethodon* 145 mm. long. The latter was still wriggling when its captor was taken. Apparently *Gyrinophilus* is quite cannibalistic in its habits. I found the second specimen of *G. d.* x *duryi* at Elkmont. I have lived at that locality four years but this salamander waited until a warm rainy night in early April, 1939, to crawl out on the highway and be discovered.

TABLE 4. Comparative measurements of a series of *Gyrinophilus danielsi*. The measurements given in the first column are based on two specimens of *G. danielsi duryi*, one of which is Weller's Type, C S N H No. 499a, taken at Carter County, Kentucky, and the other from the collection at Wilmington College, taken in Pike County, Ohio, in 1929. The second column is derived from four specimens taken in the Great Smoky Mountains at elevations from 1,000 to 2,100 feet. The last column is taken from measurements of five adult specimens collected along the State Line in Great Smoky Mountains National Park above 5,000 feet in elevation.

	G.danielsi duryi from Ohio and Kentucky	*G.danielsi* x *duryi* the foothills of the Great Smokies	*G.danielsi danielsi* high elevations in the Great Smokies
Total length	148.5	144	135.4
Head length	21	20	21.6
Body length	77.5	71	61.2
Tail length	60	55.5	52.6
Head and body	88.5	92	82.8
Head length in body length	3.25	3.5	2.8
Head width	12	12.5	13.6
Head width in head and body length	6.6	7.4	6.1

The Tennessee Valley Authority Collection at Norris has specimens of typical *G. porphyriticus* from Anderson County and Union County in East Tennessee. The private collection of Mr. Arthur Stupka, Park Naturalist at Great Smoky Mountains National Park, also contains a typical specimen of the species from Hocking County, Ohio. All of these are distinct from the *G. danielsi-duryi* complex, and appear one and the same species.

Pseudotriton montanus montanus (Baird)

The park collection contains only two specimens of this species taken within the Great Smokies. One, an adult, was taken from under a board in a muddy spot at the Sinks on Little River, at an elevation of 1,565 feet. The other, a fully grown larva, was found in an old spring house at Mount Sterling, at 1,600 feet elevation. The species is certainly rare locally.

Pseudotriton ruber schencki (Brimley)

This subspecies of *P. ruber* is widespread in the Great Smokies but the form is rare above 3,000 feet elevation. The park collection contains specimens from 17 localities. It prefers springs and muddy seeps, but may be found along small streams. There are two records from unsually high elevation for this species, both 5,000 feet: one from Boulevard Ridge collected by the writer, and the other from Hughes Ridge collected by Maurice Sullivan, former Resident Wildlife Technician. It prefers wetter places than does *G. danielsi danielsi* and shuns streams of rapid and rocky descent. I have taken the two species together on Ramsey Prong at 3,100 feet elevation, and at the Chimneys Camp Ground 240 feet lower.

After heavy rains in midsummer adults are frequently seen on roads, trails and open areas, more commonly at night, but occasionally during the day. Larvae are common in springs and small slow moving streams.

Eurycea bislineata x *cirrigera* (Green)

In addition to *E. bislineata wilderae*, which is quite distinct, another subspecies of *bislineata* occurs in the Great Smokies that for a considerable time was an enigma to me. The latter form occurs below 2,500 feet in elevation in springs, marshy areas, and small streams. It does not leave these wet places for a semi-terrestrial existence as does *E. b. wilderae*. After examining a series of 18 specimens rather closely and comparing them with *E. bislineata bislineata* from Hocking County, Ohio, and *E. b. cirrigera* from Marshall County, Alabama, it is apparent that the local specimens are intermediate with the balance of characters in favor of *E. b. cirrigera*.

The local form is recognized by its brown color. The ventral area is yellow and the dorsal area plain brown with only a few specimens showing scant spotting. The sides of the body are finely pigmented, grading from a grayish brown mottling along the ventral border to a dense dark brown dorso-laterally, sharply marked off from the lighter dorsum. The pigment pattern and general appearance of this animal is very much like that of *Eurycea multiplicata* (Cope). The species from west of the Mississippi can, however, be distinguished by a larger number (5 to 6) of costal grooves, rounder tail, slenderer head and body, and more rounded snout, as well as by differences in habits. It appears that the present form of *Eurycea* is the most primitive of the *bislineata* group and may be a relic of a much older population which gave rise to *E. bislineata bislineata, E. b. cirrigera, E. b. wilderae*, and *E. multiplicata*.

TABLE 5. Comparison of characters of *Eurycea bislineata bislineata* taken from Dunn (1926) and specimens from Ohio, with *E. b. cirrigera* taken from Dunn (1926) and a specimen from Marshall County, Alabama, with a series of *E. bislineata* from low elevations in the Great Smoky Mountains. The Great Smokies specimens are nearer *E. b. cirrigera*, both in general appearance and anatomical character as can be seen from the comparative data.

Character	*E. b. bislineata*	*E. b. cirrigera*	*E. bislineata* from low elevations in the Great Smokies
Costal grooves	15	14	14
Folds between appressed toes	3	2	2
Shape of head	broad oval	blunt, almost trapezoidal	intermediate
Length of eye as to distance to tip of snout	longer	shorter	equal
Naso-labial swelling in male	slight	well developed cirrus	pronounced tubercle
Outline of upper jaw	convex	straight	straight
Toes, in order of length	3-4-2-5-1	4-3-2-5-1	3-4-2-5-1
Tail keeled below	not keeled below, or on distal 1/3 only	on distal 2/3	on distal 1/2
Vomerine teeth	6-7 arise opposite posterior corner of nares, bend in and back and almost meet	4 arise behind inner corner of nares, remain separated by width of nares	5 to 8 arise behind inner corner of nares, remain separated
Pigment pattern	dark line from eye to tip of tail, gray mottling below, yellow venter	broad band eye to tip of tail, darkest dorso-laterally, bright yellow venter	brownish, darkest dorso-laterally, lighter dorsally, yellow venter
Dorsal spotting	median, comparatively few spots	diffuse, numerous small spots	little or none

Secondary sex characters are more highly developed than in *E. b. bislineata*, as evidenced by a well formed naso-labial tubercle, swollen snout and slightly enlarged premaxillary teeth in the male. Females with well developed eggs have been taken at Elkmont throughout March, and eggs have been noted in April. These were attached singly or in small clusters, under stones or leaves where there was sufficient flow of water to provide aeriation. A larva taken at the Park Headquarters Area, April 8, 1937, measures 54 mm. in total length. Another, with the same data, is 39 mm. long. The upper row of larval areas is visible on the smaller specimen but cannot be seen on the larger one. The middle row is clearly visible on both and the lower row very indistinct. There are 14 costal grooves between the legs. The sides of the body and tail show the formation of the brown pigment characteristic of the adult. Two small salamanders from the same locality measure 57 and 60 mm. and would pass for *E. b. bislineata*, but show a tendency toward increased pigment

on the sides of the body and tail. Apparently this increases in extent with age, for no adults have been found which might be called *E. b. bislineata.*

The form has been taken at Anthony Creek in Cades Cove, at the Laurel Creek sink holes, from a woodland pool at the Sinks on Little River, at Elkmont, Gatlinburg and the Park Headquarters area, all in Tennessee.

Eurycea bislineata wilderae Dunn

This is one of the common salamanders in the Great Smokies. It may be found in nearly every spring, seep and permanently damp place at suitable elevations. In fact, it appears fairly terrestrial in habit, and is frequently found under logs, bark of fallen trees or moss at considerable distance from water. I have not taken it below 1,700 feet, but have found it on the highest peaks, including the very top of Clingmans Dome at 6,642 feet. The park collection contains 63 specimens from 22 localities.

Weller (1931) mentions 4 specimens in the Ohio State Museum from Gatlinburg, which is at 1,300 feet elevation. I am certain that the specimens in question came from LeConte Creek in the vicinity of Cherokee Orchard at 2,600 feet elevation.

There is some variation in anatomical characters shown by a large series. This is particularly noticeable in amount of pigmentation between the dorsolateral stripes, and the extent to which the lines remain unbroken on the tail. The largest adult specimen reported by Dunn (1926) measured 93 mm. in total length and the largest larva, 51 mm. These measurements are exceeded by several specimens in the collection at Great Smoky Mountains National Park. On Baxter Creek, a tributary of Big Creek, I found a colony of exceptionally large individuals. Three of these measure 96, 98 and 99 mm., respectively. One larva is 60 mm. in length. From Road Prong, a headwater stream of the Little Pigeon, two exceptional adults were taken, one of which is 98 mm. long and the other 120 mm. Average sized adult specimens are from 60 to 90 mm. in total length.

Eurycea gutto-lineata (Holbrook)

Dunn (1926) reports collecting this species in the vicinity of Mount Sterling, North Carolina. In conversation, Dr. Dunn has told me of the methods he employed in collecting and of the streams he worked. I have searched the same streams as well as others both by day and by night, not once but many times, and still I have not encountered the species in the Great Smokies. The country has been rather severely logged and much of it burned over since Dr. Dunn collected there, but the species should at least have persisted. Probably as more work is done it will turn up some day unexpectedly.

Eurycea longicauda Green

This species is known from several scattered localities in the park at low elevations. The park collection contains specimens from Gatlinburg, the Park Headquarters area, Cades Cove, Laurel Creek and White Oak Sinks. Dunn

(1926) records one specimen from Mount Sterling. Hassler (1929) reports taking the species on "Panther Creek," which I believe is more properlv referred to as Panther Branch, a small tributary of LeConte Creek.

Eurycea lucifuga (Rafinesque)

No specimen of this species has come from within the park boundary proper, but several collections have been made at Great Smoky Mountains Caverns, in Tuckaleechee Cove. The elevation at the Caverns is not greater than 1,200 feet, and the distance less than a mile from the park. In fact, the underground stream found in the Cavern arises in part from the drainage into White Oak Sinks, which is a large sink within the park. It is likely that the species does occur in the cave in the floor at White Oak Sinks and in other coves and sinks in the Cades Cove area, but it has not been found there up to the present time.

Fig. 7. A small stream on the south side of Cades Cove, at 1800 feet in elevation. This stream offers the type of habitat preferred by *Desmognathus fuscus fuscus, Desmognathus phoca, Eurycea bislineata* x *cirrigera and Pseudotriton ruber schencki.*

Aneides aeneus (Cope)

Weller (1931) reports a single specimen of this species taken by Mr. Ralph Dury of the Cincinnati Society of Natural History, at Cherokee Orchard on the slope of Mount LeConte. This is the only Great Smokies record for the species to date and repeated search for it both at Cherokee Orchard and elsewhere has failed to bring any more specimens to light. I have seen this specimen and it is correctly reported. It is to be sought for at moderate elevations in hardwood forests, beneath bark on logs or stumps, often some distance above the ground.

Desmognathus fuscus fuscus (Rafinesque)

Salamanders of the *Desmognathus fuscus* complex present one of the most interesting taxonomic puzzles to be found in the Great Smokies. This is apparent when one examines a series of specimens representing great variation in color pattern and coming from separate isolated communities at elevations varying from 1,000 to 5,000 feet. The effect of isolation is very evident, so that a collection of the species from one watershed is almost certain to have recognizable differences from those taken only a few miles away. The principal differences are in degree of coloration and color pattern, or may be expressed in size or extent of development of the ridge on the dorsum of the tail.

The most typical specimens are taken at lower elevations. In cold springs and shallow trickles at elevations of 3,500 to 5,200 feet, the populations are commonly very light in color. Weller (1931) recognized this in collections made at Indian Gap. Recent collecting in the same locality bears out his findings. The ventral mottling is light but extends over the entire belly region. Yellow on the ventral areas and yellow or grayish brown fairly fine mottling on the dorsal areas typify such collections. The usual pattern of fusing dorsolateral light areas bordered by darker areas may or may not be in evidence. The tail is more nearly round in such specimens, but the group as a whole is readily separated from *D. f. carolinensis* which may occupy the same habitat, at least in part. Similar populations occur on Bote Mountain near Spence Field and at Haw Gap near Blockhouse Mountain.

Frequently individuals of this species are found which resemble *D. phoca*, because of their relatively large size and distinctness of the light dorsal areas. *D. f. fuscus*, however, lacks the complete lateral row of light areas between the fore and hind leg insertions, and shows at least traces of ventral mottling.

There is evidence of intergradation with *D. f. carolinensis* in the eastern end of the park. Collections from Big Creek, at an elevation of 3,000 feet are definitely intermediate in character. Big Creek is a tributary of the Pigeon River which in turn adjoins the watershed of the French Broad, where Dunn (1926) states that intergradation occurs. Dunn, however, reported both forms from Mount Sterling, in the Big Creek area. The specimens in question have the keel on the tail fairly well developed, are more robust in body than is *D. f. carolinensis* generally, but approach that form in development and arrangement of pigment.

Adult males of *D. f. fuscus* taken at low elevations are sometimes almost a jet black. A collection made on Anthony Creek at 1,800 feet elevation includes two such specimens, in which solid color predominates. Others are extremely mottled and variable in color pattern.

Eggs of the species are found in the latter half of July, at elevations of 2,000 to 3,000 feet. Its egg laying habits have been described by others, Pope (1924), and Dunn (1926). These do not seem to differ locally in essential details. The eggs are laid under moss or loose bark, which usually is a few

inches over or from permanent water. The female stays with the eggs apparently until they hatch. Recently laid eggs have been found on Little River above Elkmont from July 15 to 20. Well developed embryos were noted at Bryson Place on Deep Creek at 2,500 feet elevation on July 30, 1934.

D. fuscus fuscus is definitely a species of small waters. At high elevations it shares this habitat with *D. f. carolinensis* at least during the latter's breeding season. At lower elevations it may compete with *D. phoca,* but usually one or the other of these two species dominates a locality. Mids Branch at Elkmont, a small open stream, is excellent collecting for *D. phoca,* while an unconfined spring and marshy area on Jakes Creek a short distance away never fails to give *D. f. fuscus* in numbers. Only rarely does *D. quadra-maculatus* enter the latter's territory. This has been noted, however, a few places in the Abrams Creek watershed and in spring fed streams at high elevations. To say that all the species referred to above occupy separate habitats is not true, yet one can see preferences by careful study in any particular locality.

The difference between northern and southern races of *D. fuscus fuscus* has tempted taxonomists to recognize two subspecies. The author is of the opinion that a representative series of specimens from the Great Smokies shows as wide a range in coloration and anatomical measurements as exists between typical northern and southern representatives. It would be unwise to confuse the picture by naming local variations as subspecies. The park collections contain specimens from 24 localities.

Desmognathus fuscus carolinensis (Dunn)

What has been stated regarding the variations of *D. f. fuscus* in the Great Smokies is doubly true of *D. f. carolinensis.* Its intergradation with that species in the Big Creek watershed has been mentioned. The Carolina dusky salamander is found throughout the length of the main divide of the Great Smokies and extends its distribution laterally at suitable elevations. It occurs on the top of the Clingmans Dome, 6,642 feet, and as low as 1,400 feet at Gatlinburg. It has been taken in more than 40 localities, well distributed over the park. It is quite terrestrial in habit and may be found a considerable distance from any surface water. It should be noted in this connection that water is frequently found a short distance below the surface of the ground, and the animals are able to reach it easily through the loose overlying rocks.

The wide variation in pigment pattern and in color presented by this subspecies is enough to convince one that here is an animal still undergoing extensive variation and in process of adapting itself to a fairly complex and densely populated environment. Isolated mountain coves contain populations that differ from those in other coves, and which in turn are quite unlike specimens taken along the higher sections of the State Line. Selection of useful characters and persistence of variations seems to be still in force.

Pope (1928) brought out the relation which Dunn's *D. imitator* has to this form and correctly regarded it as a color variety of *carolinensis.* The presence of the light cheek patches, varying from yellow or orange to red is

an interesting character worthy of carefully controlled genetical experimentation. Out of a series of 285 specimens, 20 percent show yellow, orange or red colored cheek patches. However, of those collected below 3,000 feet elevation only 5 to 6 per cent have the character, while above 5,000 feet 24 per cent have yellow, orange or red cheek patches. The origin of this character, together with its possible value to the creature, is a matter for interesting conjecture, but one beyond the scope of this paper to answer.

Old males tend to grow quite dark so that only solid colors of purplish brown to black remain in many individuals. Females remain lighter and show the widest array in coloration. The colors shown vary from lemon yellow to black, with mixtures of brown, orange, red and bronze. The arrangement of pigment varies from the simple outline of rows of rounded spots shown by the *Desmognathus* larva, to a confusing array of fusion of spots, presence of a dorsal band or zi-zag pattern, to a perfectly uniform condition.

A number of localities, notably Indian Camp Creek and Ramsey Prong at 3,000 to 4,000 feet elevation support populations of this species which closely resemble *D. fuscus ochrophaeus* of the Northern Appalachians. In fact, a close comparison with specimens of the latter species taken near Aurora, West Virginia, shows no appreciable difference in body proportions or colorations. It would seem proper, however, to refer all local specimens to the form *D. f. carolinensis*.

Egg clusters have been observed under moss or leaves quite close to water, during late July and August. Larvae are abundant in the spring fed trickles and seeps, as well as in quiet pools in small streams most everywhere above 3,000 feet.

Desmognathus wrighti King

This species was first described by me (1937). It is a dwarf form, restricted to the spruce-fir forests, usually above 5,000 feet in elevation. Its small size when mature (35-50 mm.), its limited range, and its striking coloration, which is highly protective, account for its having been overlooked previously. It is typically brown, less frequently yellow or reddish, with a pattern of inverted V's usually visible on the back. It is found under logs and stones on the forest floor. It has been taken in several localities from Clingmans Dome to White Rock along the State Line, and at Flat Creek, at Mount Sterling Ridge, and on several of the high ridges extending to either side of the State Line. The lowest elevation at which it has been found is along the Road Prong, below Indian Gap at approximately 3,500 feet elevation. The species is highly terrestrial in habit.

Desmognathus phoca (Matthes)

This species has been taken at least in 30 different localities in Great Smoky Mountains National Park, from Mount Sterling Creek to Abrams Creek and from Gatlinburg to Bryson City. It is a common inhabitant of small streams, side channels of larger streams and trickles coming from springs.

It occurs at elevations between 1,200 and 5,000 feet. It is more of a stream species than *D. f. fuscus* but shuns the large boulders and cascades of mountain streams so frequently inhabited by *D. quadra-maculatus*.

Moore Spring just under Gregory Bald has the three species, *D. f. fuscus*, *D. phoca*, and *D. quadra-maculatus* living in it. The same is true of Ramsey Prong (Middle Prong Little Pigeon) and the tributaries of Abrams Creek below Cades Cove. Habitat preferences are indicated by the species concerned, but considerable overlapping exists.

Desmognathus quadra-maculatus (Holbrook)

This is the largest of the Plethodonts found in the park and is almost invariably found in or along streams above 2,000 feet elevation. Occasionally it is taken as low at 1,500 feet, as on Rabbit Creek, a tributary of Abrams Creek, and extends as high as 5,200 feet at Indian Gap. It appears to be widespread over the park and has been collected at 37 localities, including almost every principal watershed. At higher elevations it invades the springs, where it may occur in company with *D. f. fuscus* and more rarely *D. f. carolinensis* and *Gyrinophilus danielsi danielsi*.

It does not seem to vary greatly throughout the park, except that specimens from the east end, especially in Cosby Creek, are browner and grayer than the normal. The sight of several of these large salamanders on a wet boulder has been commented upon by herpetologists and laymen alike. The species is indeed agile, and one gets a good work-out collecting a series. The secret is to look for them along the stream in wet spots, rather than out in the rougher stream bed, even though they may be more abundant in the latter place. Its breeding habits are well discussed by Pope (1928).

SALIENTIA

Bufo americanus americanus Holbrook

This toad is widely distributed in the Great Smokies and may be found almost anywhere except on the highest mountain tops. The park collection contains specimens from 29 localities.

The breeding season begins with warm spring weather usually between March 15 and 30, and extends well into April. An early warm period will bring out a few individuals even during January, as occurred in 1937, and on February 12, 1938.

Some of the adult females taken locally are exceptionally large. I have three which measure 109, 110, 115 mm., respectively, in body length (No. Baa-39, 40, 74). Males have been taken which measure up to 90 mm. in body length. Toads are frequently found hibernating under large stones, in soft banks, or under heavy leaf litter.

They are more common about fairly wet open areas at low elevations, but often climb into drier woods. It is not unsual to find these toads on the high dry ridges several hundred yards from any water. American toads have been taken by me and Arthur Stupka, Park Naturalist, almost on the very top of

Fig. 9. A woodland pond in Cades Cove, where red maple, sweet gum, button bush, sphagnum moss create an animal habitat which is rare in the Great Smoky Mountains. *Chrysemys picta picta, Rana sylvatica sylvatica, R. clamitans, Bufo americanus, B. fowleri, Pseudacris nigrita feriarum, Hyla crucifer, H. versicolor versicolor, Triturus viridescens viridescens, Ambystoma maculatum* and *A. opacum* inhabit the area in and about the pond.

Mount Sterling Ridge, near the fire lookout tower at 5,800 feet. Toads apparently return to suitable breeding grounds upon reaching maturity because, of those taken so far from water, a majority are immature specimens in their second or third season's growth. Frequently individuals are encountered which are brick-red in color. This color phase seems most common on drier and higher areas.

Bufo fowleri Hinckley

Fowler's toad is less common than the American toad, but is fairly well distributed below 2,500 feet in elevation. The park collection contains specimens from 14 localities. Its occurrence above 3,000 feet is sporadic, and the highest record for the species in the park is 4,000 feet on Mount Sterling Ridge. Harper (1935) records the species from Bryson City at 1,800 feet. *B. fowleri* is definitely a lowland form. It seems to be more common in the west end of the park than in the east end, no doubt because of the generally lower elevations and more favorable breeding areas.

Fowler's toad reaches the height of its breeding season generally about two weeks later than does the American toad. Both species are often heard calling from the same pond or ditch bank, and a few breeding individuals of both species have been seen to deposit eggs the same day. It is sometimes difficult to refer small toads to one or the other of the two species but it is doubtful if cross breeding occurs except rarely. Its smaller size, smoother skin, more than one wort per dorsal color spot, greater restriction of pigment on ventral area, its vastly different and more penetrating voice serve to distinguish this toad from its relative. The habitat preferences of the two species are fairly well marked. *B. fowleri* usually stays near the breeding grounds and wanders less than does *B. a. americanus*. As mentioned above there is little conflict in their use of the same ponds or marshy area for breeding purposes, because of the later breeding season of this species.

Pseudacris nigrita feriarum (Baird)

This is one of the first frogs to emerge in the spring, and may appear during a period of warm wet weather in late winter. In fact, I have heard the species call every month during the year in the Great Smokies (1937). Mating begins soon after emergence and eggs can usually be found from late February to early April. In 1937, a premature period of spring weather brought the species out in large numbers on January 13 and egg masses were found on following days. In 1938 breeding was first observed February 11. This frog prefers small ponds, ditches and marshy meadows, and apparently does not move far from its chosen habitat. The highest elevation at which I have taken the species is 2,500 feet at Fightin Creek Gap. It avoids the rapidly flowing streams and heavily timbered areas. In some places it appears to have invaded farther into the mountains following the cutting of the forests.

I have heard this species call throughout its mating period for four spring seasons in the Great Smokies and noted that, although calls may be heard during any part of the day and night, there are two periods of greatest activity. One is in the morning, from 9 to 12 A.M., as the sun is warming the earth and air. The other is late afternoon and early evening, 4 to 9 P.M.

Many of the local specimens have the dorsal stripes partially broken up into spots, and a pigment pattern somewhat irregular. Dr. Charles Walker examined a series of the species from the park collection and pronounced them typical *P. n. feriarum*. Necker (1934) reports *P. n. triseriata* from Greenbrier. Undoubtedly the form reported is *P. n. feriarum*, as additional collections from that area indicate. The *triseriata* form does not appear to enter the Great Smokies. *P. n. feriarum* locally is quite abundant in localities where it occurs. The park collection contains specimens from 5 localities and I have heard the species in at least twenty others. As one drives north and west from the Great Smokies, the form of *Pseudacris* encountered changes shortly after one drives north or west from Sevierville and Newport. The form there encountered approaches *P. n. nigrita* in color pattern and body proportions. Certainly it is distinct from *P. n. feriarum* in the Great Smokies. The call

of *feriarum* is lower pitched and slower than the frog from the lower country beyond the foothills.

Hyla crucifer Wied

This small Hyla is found in suitable habitat in the lowlands and cleared areas of the park ,up to elevations of 4,000 feet. The park collection contains specimens from only 5 localities, but the species is widespread and abundant generally. In the spring it emerges shortly after *P. n. feriarum* appears and occupies similar habitat. When both species occur together, the spring peeper does not appear as numerous as does *Pseudacris*, but it is more widely distributed.

Its anatomy and habits do not appear appreciably different from descriptions of the species elsewhere.

Hyla versicolor versicolor (LeConte)

The tree toad is well known by local residents in the Great Smoky Mountains, and its call, frequently heard in late spring and before and after summer showers, is often commented upon. The species emerges usually in April, and tends to remain near its breeding grounds until about the first of June, after which time it is heard calling from shrubs and trees, often a considerable distance from water. Egg laying may extend well into May in this region. I have not heard the species in the mountains above 2,500 feet in elevation. The species is fairly well distributed over the park, occurring commonly in the coves along streams or ponds.

Rana catesbeiana Shaw

The bull frog occurs in the Great Smokies only on the large streams below 2,500 feet elevation. It is nowhere numerous, and fully grown individuals are rare. I have recorded the species from several localities along Abrams Creek, Little River as high as Elkmont, the West Prong of Little Pigeon River at Sugarlands, and at the pond on Cataloochee Creek. Necker (1934) records the species from Greenbrier, on the Middle Prong of Little Pigeon River, at 1,700 feet elevation. An absence of ponds and favorable habitat limits its distribution. The species has been severely persecuted by local residents, and deserves the protection afforded by the National Park Service.

Rana clamitans Latreille

The green frog is widely distributed locally in small marshes, streams, ponds and sink holes. I have taken the species at Elkmont, Park Headquarters area, Cades Cove, West Prong Little Pigeon River at 3,900 feet elevation (highest local record), Cosby Creek, Cataloochee Creek, Straight Fork and Waterville, North Carolina. Its call is frequently heard during the summer evenings. The species does not ordinarily make its appearance locally until late April, and egg laying may occur from that time through June.

Rana palustris LeConte

The pickerel frog inhabits available pools and banks of small streams in the Great Smokies. All individuals taken or recorded were at elevations

below 3,000 feet. I have specimens from Abrams Creek, Cades Cove, Elkmont, Meigs Creek, Dudley Creek, Cataloochee Creek and its tributary Caldwell Fork, and Waterville, North Carolina. The only place where I have found the frog to be abundant is along an artificial pond of not more than 3 acres, on Cataloochee Creek at an elevation of 2,100 feet. Here the species is present by the thousands. My earliest record of egg laying by the species is March 21, 1935, in Cades Cove.

Rana pipiens Schreber

The few leopard frogs which have been taken in the Great Smokies have come from the western end of the park, below 2,000 feet elevation. The form here seems to be *R. pipiens* of the north rather than the southern leopard frog, *R. sphenocephala*. I have taken the species at Chilowee, Tennessee, at 900 feet elevation and former Resident Wildlife Technician Raymond Fleetwood collected one of these frogs on Cane Creek at 1,250 feet elevation. Necker (1934) also reports taking it in Cades Cove. It is not common.

In two specimens (No. Rp-1 and 2, both males) the head length enters the body length 3 times; there are three well marked rows of spots below the lateral skin folds; the spot on the tympanum is poorly indicated; and the tibiotarsal articulation just reaches to the snout.

Rana sylvatica sylvatica LeConte

The wood frog is the first of the Salientians to make its appearance locally. Its early breeding habits have heretofore aided it in escaping herpetologists collecting in the Great Smokies region. The species is the most abundant and widespread of the *Ranidae* within the park. It breeds in ponds formed by springs and stream overflows, in sink holes, temporary pools, and in fact almost any body of still water. All park records are below 3,000 feet in elevation. I have taken the species from the following localities: Cades Cove, the sink holes near Laurel Creek, Meigs Creek, Elkmont; the Sinks on Little River, Sugarlands, Dudley Creek, Greenbrier, Cataloochee Creek, and Deep Creek.

As many as 200 of thse frogs have been seen in a pool not over 20 feet in diameter. As many as 28 egg masses have been counted attached to a single piece of brush. In 1925, the species emerged for the first time on January 21; in 1937, wood frogs were heard calling on January 13; and in 1938 on January 22. Apparently the species will emerge during any warm period in late winter. Egg laying follows in a day or two, the weather permitting. In 1938, the first eggs were noted January 23. These hatched a month later. Tadpoles of this species were seen undergoing metamorphosis at Gatlinburg June 10 to 14, 1934, and at the Park Headquarters area May 18 to 22, 1938.

This is one of the most attractively colored species of frogs, and has a remarkable ability to change from gray to various shades of red and brown. Some individuals appear almost black. The species may call throughout the day, but is most active during the warmer part of the day and early evening. Its inactivity at night probably is due to the lower night temperatures slowing physiological processes.

Gastrophryne carolinensis (Holbrook)

The narrow mouthed toad escaped my detection through three collecting seasons, but was finally encountered on August 9, 1937, in the Cades Cove area. This species seems partial to pools in limestone strata, and for that reason its distribution is greatly restricted in the Great Smokies. The animals were calling in chorus and mating on August 10, 1937, in roadside ponds and grass bordered ditches in the Cades Cove and Tuckaleechee Cove areas, the latter just outside the park.

LACERTILIA

Anolis carolinensis Voigt

The Carolina chameleon has been observed mostly in the west end of Great Smoky Mountains National Park. Wildlife technicians of the National Park Service have recorded the species from Twentymile Creek, Chilhowee, Abrams Creek and Cades Cove. It has been reported from Gatlinburg but is rare at that place. One specimen was taken on Little River at 1,600 feet elevation on November 30, 1938. Jones and Ressler (1927) reported the species from a location four miles east of Townsend on the Elkmont Pike (Tennessee Route 73). The latter is well within the park.

Sceloporus undulatus (Latreille)

The pine swift occurs throughout the park in relatively dry hardwood and oak-pine forests. It is most common on dry ridges below 3,000 feet, but may go higher, as it does on the top of Bullhead Mountain at 4,250 feet. The species is too widely distributed to necessitate giving locality records. Pine swifts have been found active during warm periods in February, as was noted February 12, 1938, along Meigs Creek, Little River, and are frequently seen during sunny days in March and April.

One specimen, No. Su-10, has a forked tail, an uncommon expression of regeneration following an injury.

Ophisaurus ventralis (Linnaeus)

This legless lizard is known from the Cades Cove area only. It is the only species listed in this report which is not supported by one or more museum specimens. The local residents of Cades Cove recognize the animal and describe it accurately. It was collected in this locality by Professor B. C. V. Ressler of the University of Tennessee, between 1928 and 1930, but the specimens were destroyed by a fire which consumed the University's Biology Building in 1932. The species inhabits cultivated areas and is considered common throughout much of Tennessee.

Cnemidophorus sexlineatus sexlineatus (Linnaeus)

The race-runner is uncommon in the park, and has been recorded only from Twentymile Creek, Abrams Creek, Chilhowee, Deep Creek, and the Sugarlands area, all below 2,000 feet elevation. Its preferred habitat, a dry, fairly open, sandy terrain is very limited in the Great Smokies.

Leiolopisma unicolor (Harlan)

This small lizard has been taken in Cades Cove, Elkmont, the Sugarlands area and near Cherokee Orchard in the Great Smokies. Probably it has a wider local distribution than the records indicate, but escapes observation because of its secretive habits. The Cherokee Orchard specimen was taken by the writer and F. O. Hazard in 1932 and is in the collection of the Biology Department, Wilmington College, Ohio.

Eumeces fasciatus (Linnaeus)

This lizard is fairly widespread over the park, below 2,500 feet elevation. The park collection contains specimens from 9 localities. It is most often seen about old buildings and wooden bridges. Eggs of the species have been encountered a number of times under large boulders in fairly dry situations, during the latter half of July.

The largest specimen of *E. fasciatus* in the park collection (No. Ef-7) measures 176 mm. in total length and 72 mm. snout to vent. A few individuals show 8 upper labials on one side or both, although 7 is the usual number.

Eumeces laticeps (Schneider)

A study of the lizards of the Genus *Eumeces* from the Great Smokies convinces one of the separate identity of *E. fasciatus* and *E. laticeps* and also shows how closely related the two are both in structure and ecology. Dr. Edward H. Taylor was kind enough to examine the park's collection of the lizards of the Genus *Eumeces* and check the identifications.

E. laticeps is a species of dry pine-oak hillsides below 2,500 feet elevation. All records from the park are from the west end and include specimens from Eagle Creek, Twentymile Creek, Chestnut Flats Road, Meigs Creek, Wears Cove Gap and Elkmont. The largest specimen (No. El-4) measures 245 mm. in total length and 113 mm. from snout to vent. The number of upper labials is generally 8 in local specimens, but 7 is a frequent number.

Eumeces inexpectatus Taylor

After examining the park's collection of lizards of the Genus *Eumeces*, Dr. Edward H. Taylor pronounced two specimens to be of this species. One of the characters noted is the smaller size of the scales on the under side of the tail than that which obtains in the related species found locally. The specimens designated *E. inexpectatus* were collected, one on Twentymile Creek, North Carolina, by former Resident Wildlife Technician Maurice Sullivan, and the other on Laurel Creek, Tennessee, by Park Naturalist Arthur Stupka. Undoubtedly the species is more widely distributed in suitable habitat and low elevations within the park.

SERPENTES

Carphophis amoena amoena (Say)

The ground snake is frequently found in the Great Smokies, in open areas, under logs and stones. It seems partial to old dwelling or barn sites, probably because of the more abundant food supply. Its known altitudinal distri-

bution extends from the lowest elevations in the park to the highest record at Rye Patch on Long Hungry Ridge at 4,300 feet. The park collection contains specimens from 9 localities.

The local form is referable to *C. a. amoena* rather than *C. a. helenae* although some specimens show a tendency toward the latter form in extent of fusion of the internasal and prefrontal scales. A series of 16 specimens contains 11 with internasals and prefrontals entirely separate, 1 with them separate on one side and partly fused on the other, 3 with them almost fused on one side and fused on the other. No specimens examined to date have these scales entirely fused on both sides. It is recognized that the population of this species in the lower foothills of the Great Smokies on the Tennessee side of the park is an intergrading one, but the best procedure is to group all specimens under *C. amoena amoena*. The largest specimen in the park collection (Caa-5), a female taken at Kephart Prong, North Carolina, by me, measures 284 mm. in total length.

Diadophis punctatus edwardsii (Merrem)

This snake is probably the most widely distributed and most abundant of any snake in the Great Smokies. It occurs from the lowest elevations, 1,000 feet, to as high as 5,800 feet on Andrews Bald. It may be found in open areas or in dense woodland. I found one individual on the top of the Chimneys, an isolated and exposed rock mass at 4,700 feet elevation. The park collection contains specimens from 13 localities.

Some of the local collections of this species show a tendency toward intergradation with the closely related subspecies *D. p. punctatus*. In a series of 8 specimens the ventrals plus caudals range from 209 to 224, and average 215. Three of the 8 specimens have the neck ring incomplete, while 5 have the ventral spotting imperfectly developed. One specimen (No. Dpe-9) has the ventral pigmented areas well developed, has an interrupted neck ring, but has 219 vntral plus caudal scales. It is referred to *D. p. edwardsii* although its pigment pattern resembles *D. p. punctatus*. Specimen No. Dpe-6 has the lowest number of ventral plus caudal scales, 209, and has the ventral spotting

TABLE 6. Anatomical data on 8 specimens of *Diadophis punctatus edwardsii* from the collection at Great Smoky Mountains National Park. Abbreviations in the Table signify: inc.—incomplete; comp.—complete; pres.—present.

Collection No.	Locality	Elevation feet	Ventral scales	Caudal scales	Total	Ventral spotting	Neck ring	Sex	Total lgth.	Tail lgth.
Dpe-2	Chimneys	4,700	158	52	210	pres-inc	inc	male	397	86
Dpe-3	Gregory Ridge	3,750	154	57	211	pres-inc	comp	male	334	79
Dpe-4	Straight Fork	3,100	157	56	213	pres-inc	comp	male	380	86
Dpe-6	Jenkin Trail Ridge	4,000	162	47	209	comp	comp	male	338	65
Dpe-7	Cades Cove	1,800	160	53	213	none	comp	female	381	81
Dpe-9	Spence Field	5,000	166	53	219	pres-inc	inc	female	418	82
Dpe-11	Andrews Bald	5,800	158	66	224	none	inc	male	353	86
Dpe-12	Sugarland Ridge	4,000	155	65	220	pres-inc	comp	male	312	78

(All measurements are in millimeters)

developed sufficiently to resemble *D. p. edwardsii*. A representative series of these snakes was examined by Mr. Roger Conant, and I follow his recommendation in calling them all *D. p. edwardsii*.

Heterodon contortrix (Linnaeus)

The distribution of this species within the park appears to be confined to elevations below 2,500 feet. Its preference for open sandy habitat is well known. The species has been collected at Cades Cove, Elkmont, Sugarlands and Cherokee. There is considerable variation in pigmentation of specimens taken locally. Two melanistic individuals are contained in the park collection. The most common color phase found is that of gray ground color with brown blotches. Adults may develop bright reddish brown, orange and yellow markings.

The largest specimen (Hc-3), from Cherokee, North Carolina, is a male measuring 860 mm. in total length.

Opheodrys aestivus (Linnaeus)

The rough green snake has been taken in the Great Smokies at Forney Creek, Deep Creek, Elkmont, Greenbrier, Gatlinburg and the Sugarlands areas. Specimens from all these localities are in the park's collection of amphibians and reptiles. The species has been found only at elevations below 2,500 feet. One female collected at Deep Creek by Maurice Sullivan, former Resident Wildlife Technician, laid eggs in captivity July 8, 1935.

Coluber constrictor constrictor (Linnaeus)

This snake inhabits old fields and areas about buildings, where apparently it finds its choice food most abundant. I have seen numbers of these snakes along Fightin Creek, a tributary of the West Prong of Little Pigeon, and at Elkmont. It has also been taken at Kephart Prong of the Oconalufty, Fish Camp Prong of Little River, and Low Gap on the State Line. Necker (1934) reports the species from Greenbrier. It has been found up to 4,000 feet in elevation.

Elaphe guttata (Linnaeus)

This is one of the handsomest snakes in the Southern Appalachians. It is fairly common below 2,500 feet elevation, in either wooded or open areas. The park collection contains specimens from Townsend, Fightin Creek Gap, Elkmont, Park Headquarters area and Forney Creek. The habit of crawling upon and resting on travelled roads costs many snakes of this species their lives. It permits handling readily.

Elaphe obsoleta obsoleta (Say)

This snake is both numerous and widespread in the Great Smokies. Collections have been made at only 4 points, but the species has been recorded at numerous other places. Specimens between 5 and 6 feet in length are not uncommon. It inhabits wooded areas, and has been seen at localities as high as 4,000 feet elevation. The ability of the species to climb trees is well known. I watched one of these snakes climb a slender grapevine, less than 1½ inches in diameter, which extended at least thirty feet up to a limb of a tree.

Lampropeltis elapsoides virginiana Blanchard

Only one specimen of this snoke has been found in the Great Smokies. This came from Round Top Mountain along the north boundary of the park, on November 20, 1935, at approximately 2,000 feet elevation. It was found hibernating in the ground by a CCC crew engaged in excavating a trail through pine-oak woods.

The red pigment does not encroach on the margins of the ventrals in the anterior two-thirds of the body, but there is a slightly reddish cast on the posterior ventral portions of the body and tail. A series of specimens might indicate the local representative of the species is other than *L. e. virginiana*, but the one specimen at hand seems to be of this geographic race.

Lampropeltis getulus getulus (Linnaeus)

A collection of five chain snakes from the Great Smokies indicates that the region is near the zone of intergradation of *L. g. getulus* and *L. g. nigra*. Although it is recognized that the small series makes for errors in interpretation, differences in color pattern and geographical position are sufficiently evident on the specimens at hand to indicate the presence of *L. g. getulus* on the North Carolina side of the Great Smokies and *L. g. nigra* on the Tennessee side. This type of distribution holds true for a surprisingly few species, considering the height and barriers of climate and forest encountered on the high divide of the Great Smokies. Descriptive measurements:

No.	*Sex*	*T.l. mm.*	*Cross bands*	*V. scales*	*Sub-caudals*
Lgg-1	Immature	287	39	197	50
Lgg-2	Male	895	36	209	54
Lgg-9	Female	1064	42	210	42

The first specimen was taken at Deep Creek, the second at Smokemont, and the third between Deals Gap and Tapoco, North Carolina. The last was found on the highway, April 17, 1938, at the southwest end of the Great Smokies. It is a beautiful specimen and is a perfect intergrade between *L. g. getulus* and *L. g. nigra*. Trapido, in a note published in Copeia (1938, No. 1) reports *L. g. nigra* from western Tennessee and states he believes *L. g. getulus* and *L. g. nigra* intergrade in the bottom lands of the Mississippi. There is ample evidence that the zone of intergradation is farther east and actually is the southwest portion of the Great Smoky Mountains, and probably extends farther south and slightly west.

Lampropeltis getulus nigra (Yarrow)

Two chain snakes collected in Cades Cove can definitely be referred to this subspecies. There is evidence of variation of characters, tending toward *L. g. getulus*, particularly in the small number of light cross bands.

Descriptive measurements:

No.	*Sex*	*T.l. mm.*	*Cross bands*	*V. scales*	*Sub-caudals*
Lgn-1	Female	616	40	210	49
Lgn-2	Female	825	50	208	49

Sub-caudals 3 and 4 on snake Lgn-2 are undivided. Cope (1898) mentions this character but states he does not believe it to be significant. Mr. Roger Conant of the Philadelphia Zoological Garden examined the snakes referred to this and the preceding subspecies, and reported the specimens as I have listed them. The chain snake is not common in the Great Smokies. A number of other specimens have been seen but were not taken because this snake is considered a valuable member of the park's fauna.

Lampropeltis triangulum triangulum (Lacépède)

The house snake inhabits both wooded and open areas in the Great Smokies, but can scarcely be considered common. Collections from the park are scattered, coming from seven different locations ranging from 1,800 to 4,600 feet.

The average number of dorsal blotches is low for this subspecies (35.5), and some specimens show a tendency for the dorsal saddles to extend down to the second row of scales (Ltt-2 and 8).

A summary of these characters is given in further explanation:

No.	Sex	Dorsal saddles on body	Dorsal saddles on tail	Blotches extend to ant. third	Blotches extend to middle	Blotches extend to post. third
Ltt-2	male	33	13	4	5	4
Ltt-4	female	33	9	3	4	3
Ltt-5	female	33	8	2	2	2
Ltt-6	male	35	8	4	5	4
Ltt-8	female	36	7	3	3	2
Ltt-9	immature	40	11	3	3	3
Ltt-10	immature	36	12	3	4	3
Ltt-11	female	36	9	4	4	3

Specimens Ltt-5 and 6, female and male, respectively, were taken in copulation on Caldwell Fork, Cataloochee Creek, May 21, 1935, by Maurice Sullivan, former Resident Wildlife Technician at Great Smoky Mountains National Park. The female resembles *L. t. syspila* greatly, as noted above, while the male is typical *L. t. triangulum*. This mating record together with the fact that the collection is from the North Carolina side of the park, throws the balance in favor of calling all our specimens *L. t. triangulum*. On the Tennessee side of the park, where intergradation is more likely to be expected, the specimens are more nearly *L. t. triangulum*.

The park collection contains specimens from Rough Creek on Little River, Bote Mountain, Jenkin Trail Ridge, and Ravensford in addition to those listed above.

Cemophora coccinea (Blumenbach)

The park collection contains one specimen of this species, taken in Cades Cove at 2,000 feet elevation, by former Resident Wildlife Technician Raymond Fleetwood. A failure to find other individuals of this snake indicates that it is rare in the park. Undoubtedly it is found only at relatively low elevations.

Natrix septemvittata (Say)

The queen snake appears to be restricted to the western end of the park, and is common only in limestone strata. The park collection contains four records from Abrams Creek and its tributaries, all 1,700 feet and lower, and one record from Twentymile Creek at 1,400 feet. The relative docility of this snake compared with the meanness of the common water snake is quite evident in handling specimens of the two species.

Natrix sipedon sipedon (Linnaeus)

The common water snake has been found in practically every watershed in the park. It ascends the streams when the forests are removed, coming to occupy higher elevations than it did originally. It is in this way enlarging its territory following man's interference with natural conditions. Ordinarily it does not invade streams bordered by heavy virgin forests very far. Usually it stays below 3,500 feet, but I have taken it at Moore Spring, just under Gregory Bold at 4,800 feet elevation. It is especially abundant on Little River below 2,200 feet, the Middle Prong of Little Pigeon below Greenbrier, Forney Creek, and the Left Fork of the Oconalufty.

The species is despised by fishermen, and at one time an effort was made to control its numbers in the park. It was later decided to conduct an investigation on the food habits of the species. A total of 98 snakes were killed by Park Wardens and examined by the writer, to learn to what extent the species fed on trout. Fifty of the stomachs were empty, so gave no clue as to feeding habits. Twenty-nine stomachs contained fish remains. Two of these definitely contained rainbow trout, and one a small-mouthed black bass. In eight stomachs the material was beyond identification except that it was originally fish. Of the non-game species, *Nocomis micropogon, Catostoma anomalum, Hypentilium nigricans* and *Cottus* sp. were the fishes commonly taken by the snakes. Seventeen stomachs contained amphibian remains, including tadpoles of *Rana* and salamanders of the Genus *Desmognathus*. Two stomachs contained invertebrate remains, one a slug and one a grasshopper. The snakes examined ranged from 10 to 39 inches in length, averaging 24.8 inches. They came from Little River (4), Middle Prong of Little Pigeon (27), Bradley Fork (3), Forney Creek (32), Deep Creek (12), and Cataloochee Creek (20). It was not believed that sufficient evidence was found to convict the water snake, but undoubtedly the species does at times feed heavily on trout. It, like most any other creature, is quick to take advantage of a readily available food supply.

At the present time the species does not appear to be on the increase and no control measures are in force. Its breeding habits are well known and local observations substantiate the usual reports. In late April or May, it is not uncommon to see a large female ardently encircled by two to a dozen smaller males, all trying to copulate with her. If she decides to move her position a writhing mass of snakes ensues. The species is one of the first to emerge in the spring. In 1938, the species was out at Elkmont on March 18. In 1936 the first record was March 1. One of these snakes was seen crawling from a snow bank at Smokemont the last week of December, 1935.

Storeria dekayi (Holbrook)

Dekay's snake has been taken only in two localities in the Great Smokies, near the top of Parson's Bald at 4,000, feet, and in the Sugarlands area at 1,500 to 1,600 feet. It doubtless is more widespread but its retiring habits have aided it in escaping observation.

Storeria occipito-maculata (Storer)

The red-bellied snake is uncommon in the Great Sbokies. It seems to prefer semi-open areas and has been collected most often under logs. Cades Cove, Laurel Creek, Tremont and Flat Creek have yielded specimens. The latter locality is interesting in that it is at 4,950 feet elevation, yet affords the type of habitat utilized by the species, namely, an open place with adequate ground cover.

Virginia valeriae valeriae (Baird and Girard)

Arthur Stupka collected one specimen of this snake in the basement of his house at Gatlinburg on August 27, 1936. The snake, a female, is exceptionally large, measuring 280 mm. in total length. Roger Conant also found one specimen of the species on Laurel Creek, August 19, 1938.

Thamnophis sirtalis sirtalis (Linnaeus)

The garter snake presents the most interesting "snake" problem in the Great Smokies. Specimens taken at lower elevations are normal in coloration while those from the spruce-fir forests and frequently elsewhere above 3,500 feet, are melanistic. This has been observed by other workers here, but sufficient data has not been gathered to solve the problem nor does the present paper attempt to do so. Garter snakes are fairly common in the Great Smokies, and may be found both in wooded and open areas. The park collection contains a series of 46 of these snakes from 32 widely distributed localities and all elevations obtainable. A majority of the specimens were taken above 4,000 feet, because of the interesting form of the species at higher elevations.

An examination of the number of rows of body scales shows no variation, nor does there seem to be appreciable differences in head scalation. The black individuals lack the dorsal and lateral stripes, and are quite dark throughout. While I have found no melanistic individuals below 3,000 feet, I have taken normally colored specimens as high as 5,000 feet, and a few specimens taken higher show very faint indications of striping. The ventral scales on 9 specimens taken above 5,000 feet average 149 in number (range 142-156); on 10 taken from 4,000 to 5,000 feet average 148 (range 142-156); on 5 taken from 3,000 to 4,000 feet average 146 (range 141-155); on 5 taken from 2,000 to 3,000 feet average 143 (range 142-151). It is doubtful if this is a significant variation that would hold true over a larger series.

There is a noticeable difference in the behavior of snakes taken from the high and low elevations. The former are much more docile and do not resist capture or handling as does the common colored phase. Differences in air temperature may account for the differences in behavior. The snakes of the

black phase appear thicker bodied than their lowland relatives. At Three Forks on Raven Fork, at 4,280 feet, both color phases occur, and the same is true for a number of other localities at comparable elevations.

The problem was presented to the late Dr. Blanchard, an authority on the group. Dr. Blanchard was of the opinion that the problem required controlled breeding experiments to solve, and that taxonomic treatment should follow. The writer concurs. This is all the more true since melanistic colonies if not races of black garter snakes are known to exist elsewhere. The writer wishes to report the existence of the form here, and hopes that proper studies can be made to determine its true status.

Tantilla coronata Baird and Girard

Park Naturalist Arthur Stupka has contributed the only specimen of the species taken in the park area. It was collected at Gatlinburg, April 5, 1936.

Agkistrodon mokasen cupreus (Rafinesque)

The copperhead is considered an uncommon snake in the Great Smokies, certainly being less abundant than the timber rattler. It is partial to old building sites, rock piles such as old stone fences, and brier thickets in former clearings. It has been taken several times from under the fallen bark about the base of dead chestnut trees. The species is not usually met with above 2,500 feet.

The park collection contains specimens from Deep Creek, West Prong Little River, Park Headquarters and Sugarlands areas, Cades Cove and Bradley Fork. Necker (1934) also reports it from Greenbrier. The species doubtless is more widely distributed over the park in favorable habitats. The smallest specimen at hand is 232 mm. in length, taken at Sugarlands August 15, 1937, and the largest, a male taken just outside my office window July 24, 1937, measures 930 mm.

Crotalus horridus horridus Linnaeus

The timber rattler is common and widespread in the Great Smokies. It has been collected at 15 localities within the park, and has been seen and reported from many others. It does not appear to enter the spruce-fir forest appreciably, and is most likely to be encountered in the rougher portions of the terrain. Second growth clearings, rocky slopes, and oak-pine woods are favorite environments.

The area on Little River near the mouth of Fish Camp Prong is probably the "snakiest" place in the park, as far as finding rattlers goes. Fire Guard Wesley Ogle found one monster 66 inches long there, and at another time a mother and seven young. The young, which were taken on August 31, 1937, average 336 mm. in total length. In this same area, I have followed a party of five people along a newly dug trail, and found a rattlesnake in striking position and distance from the passerby. It made no move until I attempted its capture.

It seems significant that with all the outdoor work which has been going

on in the park since 1933, no one has been bitten while at work or walking the trails. Snakes have been seen many times, but the only bites have come from some one playing with a rattler or attempting to capture it without knowing how. At one time (summer of 1935) there were as many as 4,000 CCC enrollees, foremen, relief workers, and National Park Service employees working every day where a rattlesnake might be encountered, and no one was bitten while on duty. There are four or five recent records of people being bitten in the Great Smokies, and none of these was fatal.

There are many local beliefs regarding the rattlesnake. A popular one is that the yellow individuals are all females and the black ones males. Upon examination this is not always borne out. The large yellow specimens usually are females, but infrequently males answer the same color description. The males tend to be darker in the posterior third of the body than do females, but females have been taken which were quite dark throughout. There are all degrees of variation between yellow and dark phases, the yellow being more common locally. Average sized adults measure about 48 inches in total length.

A rattlesnake reported taken at the head of Cosby Creek near Inadu Knob, at 5,500 feet, July 4, 1936, contained a red squirrel in its stomach. Other specimens have been found that had eaten gray squirrels and cotton tailed rabbits. The eastern chipmunk seems to be a favorite item of diet. Rarely does the timber rattler ascend higher than 5,000 feet elevation.

Testudinata

Sternotherus minor (Agassiz)

While seining for fish in Abrams Creek September 6, 1937, Dr. Carl Hubbs and I collected two of these turtles. They were taken at 850 feet elevation, well out in the stream, from under large flat rocks where they had retreated. The water is clear in Abrams Creek and the current only moderately swift. I had previously seen the species about two miles above on the same stream (August 28, 1934) but had failed to capture any specimens. It is unlikely that the species occurs in any other stream within the park.

Chelydra serpentina (Linnaeus)

The common snapper undoubtedly inhabits the lower portions of many of the streams of the Great Smokies. It occurs in Little River as high as Elkmont at 2,200 feet elevation and has been reported from the West and Middle Prongs of Little Pigeon River, the latter by Necker (1934). It is not well adapted to life in the swift, rocky streams of the higher altitudes. Several small turtles of the species, 4 to 6 inches in body length, were seen swimming in Little River near Townsend, on March 30, 1938.

Terrapene carolina (Linnaeus)

The terrapene is very common in the Great Smokies and may be found on the roads or trails in large numbers during the summer, especially after rains. I have observed the species at Parsons Branch, Cades Cove, numerous places along Little River, Mount Harrison, Sugarlands, Greenbrier, Bradley Fork, and Deep Creek. I have not found the species above 4,000 feet elevation.

It frequently makes its nest and deposits its eggs in the soft dirt of newly constructed trails. Egg laying has been noted on several occasions during June. One female was observed laying her eggs on Bote Mountain on June 11, 1937.

Chrysemys picta picta (Schneider)

The small marshy areas and ponds in Cades Cove offer suitable habitat for this species, which appears to be restricted to that section of the park. The elevation at which specimens were taken is approximately 1,750 feet. The turtle probably occurs along Abrams Creek to the mouth of the stream and may have entered the park by that route. Another possibility is that the species is a faunistic relic from an ancient peneplain and has persisted only in the Cades Cove region, because of the presence of small pools on the limestone strata.

Amyda spinifera (Le Sueur)

To date no specimens of the soft shelled turtle have been secured within the park boundaries, but it is known to occur in Little River between Walland and Townsend, the latter location at 1,100 feet, and in the West Prong of Little Pigeon below Gatlinburg. One specimen (No. As-1) was taken by Earnest Ogle, August 15, 1937, while fishing in the latter stream about two miles below Gatlinburg at approximately 1,000 feet elevation. The species probably occurs in lower Abrams Creek but has escaped detection.

Summary

The present paper aims to bring together all available data on the occurrence of amphibian and reptile species at Great Smoky Mountains National Park. A total of 70 species is reported: 25 salamanders, 11 frogs and toads, 8 lizards, 21 snakes, 5 turtles. Thirty-two or 45 per cent of these have not been previously reported from the area. The faunistic relationships of the species are given according to a modified classification used by Cain (1930) in reporting the floristic relationships of the trees of the region. Seventy-two and eight-tenths per cent of the species are considered Intraneous, meaning that they are found well within the limits of their known distribution. Of these, 42.8 per cent are widespread over the eastern United States, the southeastern United States, including the Coastal Plain, are second in number of species contributed. This region accounts for over one-third of the total species. The Southern Appalachians are recognized as the center of origin and dispersal of the lungless salamanders belonging to the family Plethodontidae. Strictly Southern Appalachian influence is confined to that group among the animals reported.

A comparison of the faunistic relationships, shown by the amphibians and reptiles with the floristic relationships presented by 125 species of native trees and tree-like shrubs, indicates a remarkable similarity in composition of forms. The percentages of species having a widespread distribution over eastern United States, those occupying southeastern United States, the Mississippi Valley,

etc., is very close in these two groups of life forms. The type of forest influences the animal species present at that place. The correlation is most evident in the spruce-fir forest at high elevations and in the pine-oak forests at low elevations.

The Great Smoky Mountains are considered the oldest mountain mass of the size in eastern United States. As such, terrestrial habitat has been afforded plant and animal species continuously since the close of the Paleozoic Era. An exception to the general absence of limestone strata is found in the Cades Cove area, where an outcrop of Knox dolomite aids in creating habitat utilized by 5 species which have not yet been found elsewhere in the park. A review of the elevations attained by the various species shows that 42 do not exceed 3,000 feet in elevation, and 18 more drop out before reaching the proximity of the 5,000 foot contour. Only 5 species are restricted to the land above 3,000 feet elevation.

The Great Smoky Mountains lie in a strategic location faunistically, and intergradation or proximity to the region of intergradation is encountered in the following species:

Necturus maculosus x *alabamensis* (Viosca)
Eurycea bislineata x *cirrigera* (Green)
Gyrinophilus danielsi x *duryi* (Weller)
Desmognathus fuscus fuscus x *carolinensis* (Dunn)
Carphophis amoena amoena x *helenae* (Kennicot)
Diadophis punctatus edwardsii x *punctatus* (Linnaeus)
Lampropeltis getulus getulus x *nigra* (Yarrow)

There is evidence that the mudpuppy of the upper Tennessee drainage is intermediate between the well known *Necturus maculosus* of the lower Tennessee and Ohio systems and a species recently described by Viosca (1937) from north central Alabama, and named *N. alabamensis*. The local race seems to be the most primitive and possibly gave rise to both the other forms.

Specimens of *Gyrinophilus danielsi* taken below 2,000 feet in the Great Smokies are readily distinguished from those taken at higher elevations, and resemble *G. duryi* as described by Weller in 1930. Sufficient evidence is at hand to designate the two forms as subspecies rather than full species. *G. danielsi*, being the older, becomes *G. danilesi danielsi* (Blatchley) and *G. duryi* a subspecies, *G. danielsi duryi* (Weller).

In only one case are different but closely related subspecies found on opposite sides of the State Line. This is true of *Lampropeltis getulus*, since the subspecies *L. g. getulus* is found on the North Carolina side and *L. g. nigra* on the Tennessee side. There is evidence of integradation between the two subspecies in the extreme west end of the Great Smokies.

The collection of amphibians and reptiles upon which this report is largely based, is kept at the naturalist and wildlife headquarters of Great Smoky Mountains National Park. The field work was done in connection with other wildlife activities, from June, 1934, to October, 1938.

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An Annotated Bibliography of the Zoology of Tennessee and the Tennessee Valley Region

Charles S. Shoup

This bibliography comprises the published papers dealing with the general zoology and the distribution of animals in Tennessee, together with certain papers on the region drained by the Tennessee River and its tributaries in western North Carolina, northern Georgia, and northern Alabama. A few titles are included from Kentucky in which forms are described or listed from areas of that state near the headwaters of the Cumberland River.

The compiler believes this list includes nearly all the useful papers on the fauna of the region, and, with the possible exception of scattered papers from obscure journals, that the listing is nearly complete through the year 1938. In this compilation, references are included from *The Migrant*, organ of the Tennessee Ornithological Society, because these shorter notes and papers often give local lists for areas in which many beginning naturalists are at work.* References from other journals of limited distribution are herein included. General works, and handbooks which deal only incidentally with this region have been omitted from this bibliography. A few of these have already been included in a preliminary bibliography published in the *Journal of the Tennessee Academy of Science*, Vol. 11, January, 1936.

This list should be useful to all investigators interested in the zoology of the southeastern states, and should serve as a basis for biological survey work in Tennessee. Examination of the index of localities will show that although collections have been reported from widely-scattered localities over the area, our knowledge of the distribution of many species is very meagre. Of the one thousand titles reported in this bibliography, more than one-half are concerned with the distribution of mollusks, insects and birds of the region.

The compiler wishes to thank Vanderbilt University for assuming a portion of the publication costs of this list, and acknowledges his indebtedness to Dr. Alvin R. Cahn, Chief of the Biological Readjustment Division, Tennessee Valley Authority, for kindly furnishing about one hundred titles and for his great interest in this effort.

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STIREWALT, M. A. 1937—*Microstomum bisipralis*, n. sp. Zool. Anz. **119**:314-320. Reported to be found at Norris Lake, Tenn.

Part 4. Mollusca.

ANTHONY, J. G. 1854—Descriptions of new Fluviatile Shells of the genus *Melania* of Lamarck from the Western States of N. America. Annals N. Y. Lyc. Nat. Hist. **6**:83-116, March, and 117-129, April. *M. athleta; M. viridula; M. nigrocincta; M. arachnoidea; M. baculum; M. incrassata; M. curvilabris; M. pagodiformis; M. eximia; M. torulosa; M. fastigiata; M. pallidula; M. angulata; M. tabulata; M. glans; M. planospira*, and *M. coronilla*, from Tenn.

———1865—Descriptions of new species of N. American Unionidae. Amer. Jour. Conch. **1**:155-164. Pls. 12-16. *Alasmodon impressa; Unio striatissmus; U. devialus*, and *U. sacculus*, from Tenn.

ARCHER, A. F. 1934—The *Polygyra tridentata* Complex. Nautilus **48**(1):20-26. July. (2):49-53. Oct.

———1938—A new species of *Polygyra* from the Great Smoky Mountains, N. Carolina. Nautilus **51**(4):135-137. April. *P. (Mesodon) jonesiana*, n. sp., from Newfound Gap, N. C. Alt. 4800 ft.

———1938—A new species of *Stenotrema* from East Tennessee. Nautilus **52**(2): 54-55. Oct. *S. waldense*, n. sp., from Doakes Creek, Campbell Co., Tenn.

———1939—A new section and a new sub-species of *Stenotrema*. Nautilus **52**(2): 98-99. Jan. *S. fraternum montanum*, n. subsp. from a range inc. Blount Co., Tenn. and Smoky Mt. area.

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———1903—Shells of Land and Water: A Familiar Introduction to the study of Mollusks. Mumford. Chicago. 1-175. Inc. forms common to Tenn.

———1911—The Lymnoeidae of North and Middle America, recent and fossil. Chicago Acad. Sci. Special Publ. **3**:1-539. Illus.

BAKER, H. B. 1928—Minute American Zonitidae. Proc. Acad. Nat. Sci. Philad. **80**:1-44. Pub. May 16, 1928. *Paravitrea capsella* from *Helix capsella* Gould of 1851. Tennessee.

———1929—New Southern Appalachian Land Snails. Nautilus **42**(3):86-93. 1 pl. *Helicodiscus* (subg. *Hebetodiscus*) *singleyanus inermis; Paravitrea (Paravitreops) walkeri* v. *dentata; P. variabilis; Gastrodonta aldrichiana; Pilsbryna aurea*, from Tenn.

———1929—Pseudohyaline American Land Snails. Proc. Acad. Nat. Sci. Philad. **81**:251-266. 3 pls. Inc. *Pilsbryna aurea*, Unicoi Co., Tenn.; *Helicodiscus singleyanus inermis*, Marion Co.; *Zonitoides (Pseudohyalus) patuloides* (Pilsbry) from the Great Smoky Mts.

———1930—The North American Retinellae. Proc. Acad. Nat. Sci. Philad. **82**: 193-219. 6 pls. Inc. *Retinella rhoadsi austrina; R. cryptomphala solida; R. praecox*, and *R. sculptilis subdola*, from Tenn.

———1930—The Land Snail Genus *Haplotrema*. Proc. Acad. Nat. Sci. Philad. **82**:405-425. Pub. Jan. 29, 1931. *H. (Geomene) concavum concavum* (Say) from Carter and Unicoi Cos., Tenn. p. 411.

———1931—Nearctic vitreine Land Snails. Proc. Acad. Nat. Sci. Philad. **83**:85-117. 8 pls. In the genus *Pilsbryna*, the anatomy of *P. castanea*, and *P. aurea*, from Tennessee, are described.

BANKS, G. S. 1932—Some Land Shells from Grandfather Mountain, N. Carolina. Nautilus **45**:138-139.

BARBER, M. D. 1918—*Helix nemoralis* in Knoxville, Tennessee. Nautilus **31**:107. Jan.

BINNEY, W. G. 1858—The Complete Writings of Thomas Say on the Conchology of the United States. Ed. by W. G. B. New York. See Smithsonian Bibliography **5**.

———1863—Bibliography of North American Conchology previous to the Year 1860. Part I. American Authors. Smithsonian Misc. Coll. **5**(142):1-650.* Contains a complete listing of papers with species and localities to the date mentioned. Many references to local Tennessee species.

———1865—Land and Fresh-Water Shells of North America. Part I. 316 pp. 1869; Part II. 161 pp. 1865; Part III. 120 pp. 1865.

———1873—Catalog of the Terrestrial Air-Breathing Mollusks of N. America, with notes on their geographical range. Bull. Mus. Comp. Zool. Harvard Coll. **3**: 191-220.*

———1885—A Manual of American Land Shells. Bull. U. S. Natl. Mus. **28**:1-528.* For. Tenn. 34-36.

———1931—William Greene Binney. Biog. Note. Nautilus **45**(2):37-41. Oct.

BOEPPLE, J. F. AND R. E. COKER. 1912—Mussel Resources of the Holston and Clinch Rivers of Eastern Tennessee. U. S. Bur. Fisheries. Report of the Fish Comm. Doc. no. **765**. 1-13. Sept. 23.*

CALL, R. E. 1885—Geographical Catalog of the Unionidae of the Mississippi Valley. Bull. Des Moines Acad. Sci. **1**:1-57.

CLAPP, G. H. 1899—Shells collected at Oakdale, Morgan County, Tennessee. Nautilus **13**(6):70-71. Oct. *Polygyra stenotrema; P. exoleta; P. wetherbyi; P. tridentata; P. appressa sculptior; P. appressa perigrapta; Omphalina laevigata*, and *Gastrodonta interna*.

———1904—New forms of *Polygyra* from Alabama. Nautilus **18**(8):85-86. Dec. *P. barbata*, Wetumpka, Ala. *P. stenotrema seminuda*, Blount Springs, Ala.

———1915—*Vitrea cryptomphala*, n. sp., with notes on the *indentata* group. Nautilus **29**(3):25-28. Knoxville and Fayetteville, Tenn.

———1916—*Polygyra brevipila cherokeensis*, n. subsp. Nautilus **30**(1):3-4. May. Type locality: Pleasant Gap. Cherokee Co., Ala. Alt. 1200 ft.

———1919—New Land Shells from Alabama and Tennessee. Nautilus **33**:8-10. July. *Polita cumberlandiana*, n. sp., from Jackson Co., Ala. and Franklin Co., Tenn. *Vitrea (Paravitrea) pilsbryana*, n. sp., Franklin Co., Tenn.

———1920—*Vitrea (Paravitrea) multidentata* and *lamellidens*. The Nautilus **33**(4): 115-118. April. Localities: Thunderhead, Gt. Smoky Mts.; Oakdale, Morgan Co., Tenn.; Anderson, Franklin Co., Tenn.; Sherwood, Franklin Co., Tenn.; Watauga Co., N. C.; Mitchell Co., N. C. and Stevenson, Ala.

———1920—A new species of *Pyramidula* from Alabama and notes on *P. cumberlandiana* with new varieties. Nautilus **34**(1):23-26. July. *P. picta*, n. sp., from Anderson, Franklin Co., Tenn. with desc. of new var. from Ala. and Tenn.

CLENCH, W. J. 1925—Notes on the genus *Physa* with descriptions of three new subspecies. Occ. Papers, Mus. Zool. Univ. of Mich. **161**:1-10. 1 pl. May 27. *P. pomilia hendersoni*, n. subsp. Range inc. Tennessee.

———1926—Some notes and a List of Shells of Rio, Kentucky. Nautilus **40**:7-12 and 65-67.

———1926—Three new species of *Physa*. Occ. Papers, Mus. Zool. Univ. of Mich. **168**:1-6. Feb. 18. *P. goodrichi*, upper Tennessee drainage. So. Fork, Powell River.

———1928—*Io fluvialis turrita* Anthony. Nautilus **42**(1):36. Young specimen from Little River.

——— AND G. S. BANKS. 1932—Land Shells collected in southwestern N. Carolina. Nautilus **46**(1):14-18. July. (2):58-59. Oct. Lists from Nantahala Gorge, Swain Co.; Valley River Mts., Cherokee Co.; and Andrews, Cherokee Co.

——— AND A. E. ARCHER. 1933—Two new land Shells from the Southern Appalachians. Nautilus **46**(3):86-91. Jan.* *Polygyra sana*, and *P. stenotrema*, subsp. *turbinella*. A list of 25 species from Mt. Le Conte, Tenn. is included.

———1937— Notes on three rare American *Polygyra*. Nautilus **51**(1):17-18. July. *P. chilhoweensis* Lewis, from 4 mi. south of Byrdstown, Pickett Co. and from Alpine, Overton Co., Tenn.

COCKERELL, T. D. A. 1900—A new *Philomycus*. Nautilus **14**:59. *P. secretus;* N. Carolina.

———1918—*Helix nemoralis* at Knoxville, Tennessee. Nautilus **31**:103. April.

COKER, R. E. 1919—Fresh-Water Mussels and Mussel Industries of the United States. Bull. U. S. Bur. Fisheries **36**:13-89. 1917-1918. Doc. 865, issued October 25, 1919. For Tenn. see p. 22.

CONRAD, T. A. 1834—Description of some new species of Fresh-Water Shells from Alabama, Tennessee, etc. Amer. Jour. Sci. & Art. **25**(2):341. Jan. *Unio coelatus, U. subtentus*, Tennessee, Elk, and Flint Rivers.

———1834—New Fresh-Water Shells of the U. S. with colored illustrations, and a Monograph of the genus *Anculotus* of Say: also a Synopsis of American Naiades. Philad. Lists *Unio oviformis; Melania salebrosa; Anculotus praerorsus; A. subglobosus;* and *A. plicatus* from the Tennessee and Holston Rivers.

———1836-1838—Monography of the Family Unionidae, or Naiades of Lamarck, of North America. Philad.* Publ. as parts 1-13. Tennessee species listed in parts 2-12. See Binney Bibliography. 30-36.

———1866—Description of a new species of *Unio*. Amer. Jour. Conch. **2**:107. 1 pl. *U. depygis* from the Harpeth River, Tennessee.

DALL, W. H. 1908—Notes on *Planorbis* and its Subdivisions. Proc. Malacos. Soc. London **8**:141.

DAVIS, G., A. A. O'KELLY, AND D. BACHTEL. 1934—The Snails of Snail-Shell Cave,

Tennessee. Jour. Tenn. Acad. Sci. **9**(1): 47-50. 17 species from Rutherford County, Tenn. Not identified by modern nomenclature.

DeKay, James E. 1843—Zoology of New York. Part V. Mollusca. 4to. 1-271. 40 pls. Albany. A State report, listing forms from outside the state and inc. 47 species from Tennessee. See Binney Bibliography. 100-123.

Ferris, James H. 1900—Collecting in the Great Smoky Mountains. (Gastropods). Nautilus **14**(5):49-59. Sept. Numerous species are listed together with comment on travel conditions of the time.

Férussac. 1821—Tableaux Systems de la Famille des Limaçons. **95**:33. *Helix linguifera* Férussac, "les environs de Nogeville, état de Tennessé."

Frierson, L. S. 1900—A new Alabama *Unio*. Nautilus **13**:109-110. *U. hagleri.*

———1916—Observations on the *Unio cor* of Conrad. Nautilus **29**(9):102-104. Jan. *U. cor.* Conrad, native of Elk and Flint Rivers, Tennessee.

———1927—A Classified and Annotated Check-List of the North American Naiades. Baylor Univ. Press. Waco, Texas. 5-111.*

Goodrich, Calvin. 1921—River barriers to aquatic animals. Nautilus **35**(1):1-4. July. Refers to Tennessee River conditions.

———1921—Something about *Angitrema*. Nautilus **35**(2):58-59. Oct. Collections from Centerville, Hickman Co.; Columbia, Maury Co.; Bellevue, Davidson Co.; and Kingston Springs, Cheatham Co., Tennessee.

———1921—Anculosae north of the Alabama drainage. Nautilus **35**(1):9. July.

———1923—Variations in *Goniobasis edgariana* Lea. Nautilus **36**(4):115-119. April. Collections from Calfkiller, Putnam Co.; Sparta, White Co.; McMinnville, Warren Co.; Riverhill, White Co.; Falls City, Warren Co.; Butts Creek, DeKalb Co.; and Stone's River, Rutherford Co., Tennessee.

———1924—Some old Pleurocerids and a new one. Nautilus **38**:43-48. *Goniobasis clenchi*, n. sp., *G. dooleyensis* Lea, from Newton, Dale Co., Ala.

———1925—The genus *Gyrotoma*. Misc. Publ. Mus. Zool. Univ. of Mich. **21**:1-32. 2 pls. Also in Geol. Survey of Ala. Museum paper no. 7. 1924.

———1928—Strephobasis: A Section of Pleurocera. Occ. Papers, Mus. Zool. Univ. of Mich. **192**:1-18. 2 pls.* Refers particularly to Tennessee species and their distribution. *P. walkeri;* Sequatchie River.

———1928—The group of *Goniobasis catenaria*. Nautilus **42**(1):28-32. July. Discusses related groups from East Tennessee.

———1930—*Goniobases* of the vicinity of Muscle Shoals. Occ. Papers, Mus. Zool. Univ. of Mich. **209**:1-25. Feb. 3.* Also in Geol. Survey of Ala. Museum paper no. 10. 1930.

———1931—*Pleurobema aldrichianum*, a new Naiad. Occ. Papers, Mus. Zool. Univ. of Mich. **229**. August 29. From Polk Co., Tennessee.

———1931—The Pleurocerid genus *Eurycaelon*. Occ. Papers, Mus. Zool. Univ. of Mich. **223**:1-9. 1 pl. March 13.* Of the Tennessee River system.

———1931—Some Conchological Beginnings. Nautilus **45**(2):41-47. Oct.* Early history and travel of collectors; Lea, Conrad, Anthony, et al. in Tennessee.

———1934—Studies of the Gastropod Family Pleuroceridae. I. Occ. Papers, Mus. Zool. Univ. of Mich. **286**. June 7.* For Tenn., see p. 8.

———1934-1937—Studies of the Gastropod Family Pleuroceridae. Occ. Papers, Mus. Zool. Univ. of Mich. II. **295**. June 30, 1934; V. **318**. July 10,1935; VI. **347**. March 8, 1937.* This series contains important Tennessee and Tennessee River records, with information on distribution and variation.

———1938—Studies of the Gastropod Family Pleuroceridae. VII. Occ. Papers, Mus. Zool. Univ. of Mich. **376**:1-12. May 27.* *P. parvum*, Little River, Blount Co.; *Lithasia verrucosa*, Tenn. River, Knoxville and Muscle Shoals. *Anculosa praerosa*

and *A. subglobosa*, with varieties from several localities in Tennessee. A discussion of distribution and variation in form.

GRATACAP, L. P. 1901—Catalogue of the Binney and Bland Collection of the Terrestrial Air-Breathing Mollusks of the U. S. and Territories in the American Museum of Natural History, with enumeration of types and figured specimens, and supplementary notes. Bull. Amer. Mus. Nat. Hist. N. Y. **14**(Art 23):335-404. 6 pls. 6 maps.* Many Tennessee species are listed, too numerous to include in this bibliography.

HALDEMAN, S. S. 1840-1844—A Monograph of the Limnaides and other Fresh-Water Univalve Shells of N. America. Philad. Nos. 1-8. Lists 11 shells from Tenn. See Binney Bibliography. p. 65.

———1842—Description of five new species of N. American Fresh-Water Shells. Jour. Acad. Nat. Sci. Philad. **8**:200-202. *Physa globosa*, Nolichucky R.; *Unio abacus*, Holston R.; and *Anodon plicatus*, Cumberland R., Tennessee.

———1846—Description of *Unio abacoides*, a new species. Amer. Jour. Sci. & Art. N. S. **2**:274. From East Tennessee.

HICKMAN, M. E. 1937—A Contribution to the Mollusca of East Tennessee. Bound thesis. Univ. of Tenn. Library. Knoxville.

HINKLEY, A. A., AND P. MARSH—List of Shells collected in central Tennessee. Aledo, Ill. (Have no record of pub. date.)

———1904—List of Alabama Shells collected in October and November, 1903. Nautilus **18**(4):37-45. August (5):54-57. Sept.

———1920—A new species of *Goniobasis*. Occ. Papers, Mus. Zool. Univ. of Mich. **78**:1-3. March. 1. *G. goodrichi*, from Swan Cr., 5 mi. E. of Aetna, Hickman Co., Tenn.

———1920—Anson A. Hinkley. Obit. with Photo. By B. Walker. Nautilus **34**(2):55-57. Oct.

JAY, JOHN C. 1852—A Catalog of the Shells, arranged according to the Lamarckian system, etc., contained in the collection of John C. Jay, M.D. 4th ed. N. Y. 1-478. Lists many Tennessee species of the genera *Unio, Helix, Bulimus, Melania, Anculotus, Symphynota*. See Binney Bibliography. 172-218.

JOHNSON, D. W. 1905—The Distribution of Freshwater Faunas as evidence of Drainage Modifications. Science, N. S. **21**:588-592.* Consideration of the Tennessee R. system from the point of view of molluscan distribution.

KUNZ, GEORGE F. 1897—The Fresh-Water Pearls and Pearl Fisheries of the United States. Bull. U. S. Fish Comm. **17**:373-426. For Tennessee, see p. 400.

KUTCHKA, GORDON M. 1938—New varieties of *Anguispira* and *Discus*. Nautilus **52**(1):11-14. July. *Discus patulus brooksi; D. p. angulatus*, and *D. bryanti tuberculatus:* new varieties for Tennessee.

LEA, ISAAC. 1830-1831—Observations on the Naiades, and descriptions of new species of that and other families. Trans. Amer. Philos. Soc. Philad. **4**:63-121. 15 pls. *Unio multiplicatus; U. pustulatus; U. lens; Melania tuberculata; M. acuta*, from Tennessee River. *Carocolla helicoides; Valvata arenifers*, Nashville. *Unio arcoeformis*, Tennessee R. *Melania elongata*, West Tennessee.

———1832-1834—Observations on the Naiades, and descriptions of new species of that and other families. Trans. Amer. Philos. Soc. Philad. **5**:23-119. (Consisting of 4 parts and an index). *Unio capsoeformis*, Cumberland R.; *U. ravenelianus*, French Broad R.; *U. haysianus*, Cumberland R.; *U. dromas* and *U. perdix*, Harpeth R.; *U. troostensis* and *U. nashvillianus*, Cumberland R.; *U. pictus*, Harpeth R., Tennessee.

———1834-1838—Description of new freshwater and land Shells. Trans. Amer. Philos. Soc. Philad. **6**:1-154. Art. I. 24 pls. Lists 16 species from Tennessee. See Binney Bibliography. 440.

———1840—Descriptions of new freshwater and land Shells. Proc. Amer. Philos.

Soc. Philad. **1**:284-289. (This paper, with plates, may be found in Trans. Amer. Philos. Soc. **8**:191-229.) Lists 20 species from Tennessee. See Binney Bibliography. 423.

———1841—New Fresh-Water and Land Shells. Proc. Amer. Philos. Soc. Philad. **2**:11-15. Lists many Tennessee species.

———1841—Continuation of paper on Fresh-Water and Land Shells. Proc. Amer. Philos. Soc. Philad. **2**:30-34. Lists 11 species from Tenn.

———1841—Continuation of Mr. Lea's paper on Fresh-Water and Land Shells. Proc. Amer. Philos. Soc. Philad. **2**:81-83. (This paper was published in 2 parts in Trans. Amer. Philos. Soc. **8**:242-245, and **9**:17-23.) Lists 9 species from Tennessee, French Broad, Holston, and Caney Fork Rivers.

———1845—Descriptions of new Fresh-Water and Land Shells. Trans. Amer. Philos. Soc. Philad. **10**(1):67-101. Also Proc. Amer. Philos. Soc. **4**:162-168. Lists 8 species from Holston and Clinch Rivers, Tennessee.

———1852—Descriptions of new species of the family Unionidae. Trans. Amer. Philos. Soc. Philad. **10**:253-294. *Unio clarkianus*, Williamsport; *U. stewartsonii*, Chattanooga R.; *Anodonta denigrata*, Campbell Co.; *A. shaefferiana*, Horn Lake Cr.; and *A. oblita*, Campbell Co., Tennessee.

———1852—Description of a new genus *(Basistoma)* of the family Melaniana, together with some new species of American Melaniae. Trans. Amer. Philos. Soc. Philad. **10**:295-302. *Melania sculptilis; M. clarkii; M. oblita; M. sellersiana; M. saffordii*, and *M. pinguis*, from Tennessee.

———1857—Description of six new species of Uniones from Alabama. Proc. Acad. Nat. Sci. Philad. **9**:83. From Florence and Tuscumbia, Ala.

———1858—Descriptions of new species of *Unio* from Tennessee, Alabama, and North Carolina. Proc. Acad. Nat. Sci. Philad. **10**:40-41. *U. turgidulus*, Cumberland R.; *U. perradiatus*, Florence, Ala.; *U. mederithii*, Tenn. R.; *U. virescens*, Tenn. R.; and *U. pybasii*, from Florence, Ala.

———1858—Descriptions of a new *Helix* and two new *Planorbes*. Proc. Acad. Nat. Sci. Philad. **10**: 41. March. *Helix clarkii*, Cherokee Co., N. C. *Planorbis wheatleyi*, Montgomery Co., Ala.

———1858—Descriptions of twelve new species of Uniones and other fresh-water Shells of the U. S. Proc. Acad. Nat. Sci. Philad. **10**:165-166. July. Inc. *Unio chattanoogaensis*, from Tenn.

———1860—Descriptions of five new species of Uniones from North Alabama. Proc. Acad. Nat. Sci. Philad. **12**:86, 92, 93. Species from Muscle Shoals area.

———1860—Descriptions of seven new species of Unionidae from the U. S. Proc. Acad. Nat. Sci. Philad. **12**:306-307. *Unio lesleyi*, Ky. and Tenn.; *U. lindsleyi* and *U. perpictus*, from Tenn.

———1861—Descriptions of twenty-five new species of Unionidae from Georgia, Alabama, Mississippi, Tennesee and Florida. Proc. Acad. Nat. Sci. Philad. **13**:38-41. For Tenn.: *Unio perpurpurens* and *Margaritana quadrata*.

———1861—Description of a new genus *(Strephobasis)* of the family Melanidae. Proc. Acad. Nat. Sci. Philad. **13**:96. *S. spillmanii; S. cornea; S. clarkii*, Tenn. R.

———1861—Descriptions of eleven new species of the genus *Unio* from the U. S Proc. Acad. Nat. Sci. Philad. **13**:391-393. *U. tesserulae*, from Tenn.

———1861—Description of seven new species of the genus *Io*. Proc. Acad. Nat. Sci. Philad. **13**:393-394. *Io nodosa; I. robusta; I. variabilis; I. modesta; I. spillmanii; I. gracilis*, and *I. viridula*. Tennessee and Coosa Rivers.

———1862—Descriptions of ten new species of Unionidae of the U. S. Proc. Acad. Nat. Sci. Philad. **14**:168-169. *Unio gerhardtii*, Chattanooga, Tenn.

———1862—Description of a new genus *(Trypanostoma)* of the family Melanidae, and of forty-five new species. Proc. Acad. Nat. Sci. Philad. **14**:169-175. Lists 28 new species from Tennessee and N. Alabama.

———1862—Description of a new genus *(Goniobasis)* of the family Melanidae and eighty-two new species. Proc. Acad. Nat. Sci. Philad. **14**:262-272. May. Inc. 19 species from Tenn. See Binney Bibliography.

———1862—Descriptions of eleven new species of Melanidae of the U. S. Proc. Acad. Nat. Sci. Philad. **14**:272-273. *Strephobasis carinata*, Tenn. R.; *S. olivaria*, Knoxville; *Lithasia downei*, Cumberland River.

———1863—Descriptions of fourteen new species of Melanidae and one *Paludina*. Proc. Acad. Nat. Sci. Philad. **15**:154-156. May. From Cumberland Gap, Tenn. Florence, Ala., and Cumberland and Powell Rivers, Tenn.

———1864—Descriptions of eleven new indigenous species of Melanidae. Proc. Acad. Nat. Sci. Philad. **16**:3-5. Jan. Gives 8 species from East Tennessee.

———1864—Descriptions of thirteeen new species of Melanidae of the U. S. Proc. Acad. Nat. Sci. Philad. **16**:111-113. April. *Goniobasis pulla*, Cumberland Gap. *Trypanostoma corneum*, and *T. napoideum*, from Tenn.

———1864—Descriptions of twenty-four new species of *Physa* of the U. S. and Canada. Proc. Acad. Nat. Sci. Philad. **16**:114-116. April. *P. saffordii*, Lebanon, Tenn.

———1865—Descriptions of eight new species of *Unio* of the U. S. Proc. Acad. Nat. Sci. Philad. **17**:88-89. May. *Unio punctatus*, Caney Fork River, and *U. lyonii*, from East Tennessee.

———1867—Descriptions of five new species of Unionidae and one *Paludina* of the U. S. Proc. Acad. Nat. Sci. Philad. **19**:44-45. April *Unio clinchensis*, from the Clinch and French Broad Rivers, Tenn.

———1868—Descriptions of sixteen new species of the genus *Unio* of the U. S. Proc. Acad. Nat. Sci. Philad. **20**:143-145. April. *U. cylindrellus*, Duck River, and *U. planior*, from Tenn.

———1871—Descriptions of twenty new species of Uniones of the U. S. Proc. Acad. Nat. Sci. Philad. **23**:189-193. Oct. Lists 14 new species from Tenn. and North Ala.

———1872—Descriptions of twenty-nine species of Unionidae from the U. S. Proc. Acad. Nat. Sci. Philad. **24**:155-161. June. Lists 7 species from Tenn. and the Muscle Shoals region.

LEWIS, JAMES. 1870—Catalog of the Shells of the Coosa River, Alabama. Amer. Jour. Conch. **5**:166. Feb.

———1871—On the Shells of the Holston River. Amer. Jour. Conch. **6**(3):216.

———1871—Land Shells of East Tennessee. Amer. Jour. Conch. **6**:188.

———1876—*Io* and its habits. Amer. Nat. **10**:321.

MARSH, W. A. 1902—Description of a new *Unio* from Tennessee. Nautilus **15**:115-116. *U. andrewsii*.

———1902—Description of a new *Unio (beauchampi)* from Tennessee. Nautilus **16**:7-8. 1 pl.

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PETRUNKEVITCH, A. 1925—A new Erigoninae from Tennessee. Jour. N. Y. Entom. Soc. **33**:170-176. 1 pl.

———1932—Collecting *Hypochilus* (Arachnida). Jour. N. Y. Entom. Soc. **40**:19-23. *H. thorelli* from various mt. ranges in Tenn., N. C., and Ga. Also *Marpissa californica*, new to Tenn.

Part 7. Insecta

ABBOTT, J. F. 1913—Corixidae (Hemiptera) of Georgia. (With description of localities by J. C. Bradley). Bull. Entom. Soc. Brooklyn **8**:81-93.

AINSLIE, G. G. 1930—The Bluegrass Webworm. (Lepidop.) U. S. D. A. Tech. Bull.

173:1-26. 4 figs. *Crambus teterrellus* Zinck., continuously abundant in blue grass regions of Ky. and Tenn. Methods of control.

ALLARD, H. A. 1916—Some northern Georgia Acrididae. (Orthop.) Canadian Entom. **48**:274-279.

ALEXANDER, CHARLES P. 1926—Undescribed species of the genus *Limnophila* from Eastern N. America. I. Bull. Entom. Soc. Brooklyn **21**(3):109-115. *L. serotinella* and *L. nigrogeniculata*, from Tenn.

———1926—Undescribed species of Crane-Flies from the U. S. and Canada. II. Insec. Inscit. Menstruus **14**:114-122. *Elliptera tennessa* and *Molophilus auricomus*, from Tenn.

———1926—Undescribed species of Crane-Flies from the Eastern U. S. III. Entom. News, etc. Philad. **37**(9):291-297. Nov. *Tipula brevifurcata*, Tenn.

———1926—Undescribed species of *Dicranoptycha* from Eastern N. Ameria. Psyche **33**(2):54-59. *D. megaphallus*, Tenn.

———1927—Undescribed species of Crane-Flies from the Eastern U. S. and Canada. Entom. News, etc. Philad. **38**(6):161-184. June. *Tipula maculipleura*, from Tenn.

———1927—Undescribed species of the genus *Limnophila* from Eastern N. America. Bull. Entom. Soc. Brooklyn **22**:56-64. *L. (Phylidorea) adustoides*, Tenn.

———1927—Undescribed species of the genus *Limnophila* from Eastern N. America. III. Bull. Entom. Soc. Brooklyn. **22**:110-115. *L. (Phylidorea) subsimilis*, from Tenn.

———1929—New Nearctic Crane-Flies. XIII. Canadian Entom. **61**(1):15-22. 4 figs. *Dicranota notabilis*, from Tenn.

———1929—Undescribed species of Eriopterine Crane-Flies from the U. S. and Canada. Jour. N. Y. Entom. Soc. **37**(1):49-58. *Erioptera chrysocomoides*, from Tenn.

ALLEN, H. W. 1929—An annotated List of the Tachinidae of Mississippi. Annals Entom. Soc. Amer. **22**:676-690.

ASHMEAD, WILLIAM H. 1888—Descriptions of new Braconidae in the collection of the U. S. National Museum. Proc. U. S. Natl. Mus. **11**:611-671. *Urosigalphus armatus*, n. sp. from Tenn.

BANKS, NATHAN. 1905—Descriptions of Neuropterous Insects from the Black Mountains, N. Carolina. Bull. Amer. Mus. Nat. Hist. New York. **21**(12):215-218.*

———1915—Geographic Distribution of the Neuropteroid Insects, with an analysis of the American Insect fauna. Annals Entom. Soc. Amer. **8**:125-135.*

BARBER, H. S. 1928—Two new Cave-Beetles related to *Anophtalmus pusio* Horn. Jour. Washington Acad. Sci. **18**(7):194-196. *A. engelhardti*, from Tenn.

BARKLEY, M. A. 1927—Seasonal Succession of insect life in a cornfield. Bound thesis. 1-62. Peabody Coll. Library. Nashville. August. Locality: Central Tennessee.

BEAMER, R. H. 1930—Some *Erythroneura* of the *obliqua* group. Annals Entom. Soc. Amer. **23**(3):417-456. 3 pls. *E. bifurca; E. harpax; E. obvia; E. latapax;* Tenn.

———1931—Some *Erythroneura* (Grape-leaf hoppers) of the *maculata* group. Canadian Entom. **63**(6):127-135. Inc. *E. contracta*, from Kan. Ill. and Tenn.

———1932—Some *Erythroneura* of the *maculata group*. Canadian Entom. **63**(10):240-244. (11):268-270. (12):285-289, 1931. **64**(1):12-17. (2):45-48. (3):69-72. (4):82-88. (6):134-144. (7):158-162. (8):174-181. (9): 3 pls. Inc. *E. bispinosa; E. calamitosa; E. paravipes; E. teres; E. clavipes; E. arta*, and *E. rotunda*, from Tenn.

BENTLEY, GORDON M. 1905—The Control of Insects, Fungi, and other Pests. Bull. Agric. Exp. Sta. Univ. of Tenn. Knoxville. **18**(4):33-45. Dec.

———1906—The San José and other injurious scale insects of Tennessee, with methods for their control. Bull. Agric. Exp. Sta. Univ. of Tenn. Knoxville **19**(76):13-34. Dec.

BEUTENMULLER, W. 1903—Description of a new Moth from N. Carolina. Bull. Amer. Mus. Nat. Hist. **19**:585. *Olene*, n. sp.

———1913—A new *Nomaretus* from Mt. Mitchell, N. Carolina. (Coleop.) Insec. Inscit. Menstruus (a monthly jour. of entom.) Washington **1**:139-140.

———1918—Notes on the *Cychrus* found in the Black Mountains, N. Carolina. (Coleop.) Bull. Entom. Soc. Brooklyn **13**:89-90.

BLACKMAN, M. W. 1922—Mississippi Bark Beetles. Miss. Agric. Exp. Sta. Bull. **11**:1-130. 18 pls. 1 map.

BLATCHLEY, W. S. 1920—Orthoptera of Northeastern North America. Nature Pub. Co. Indianapolis. 1-784. Refers to Tenn.*

BOWDITCH, F. C. 1908—Notes on *Pachybrachys*. Entom. News, etc. Philad. **19**: 216-217. May. *P. spumarius;* Tenn.

BRAUN, ANNETTE F. 1935—Notes and new species of Microlepidoptera. Trans. Amer. Entom. Soc. **61**(1):45-52. *Zelleria gracillariella*. Larvae web leaves of *Ribes* in Tenn. *Lithocolletis rhododendrella* mines leaves of *Rhododendron* in Tenn.

BRIMLEY, C. S. 1908—N. Carolina records for Odonata for 1906 and 1907. Entom. News, etc. Philad. **19**:134-135.

———1920—Notes on N. Carolina Dragonflies. Entom. News, etc. Philad. **31**: 138-139.

———1921—The Bee-Flies of N. Carolina. Entom. News, etc. Philad. **32**:170-172.

———1922—List of the Tachinidae (Diptera) of N. Carolina. Entom. News, etc. Philad. **33**:20-26.

———1922—Additional Data on N. Carolina Tabanidae, Bombyliidae, and Tachinidae. (Diptera). Entom. News, etc. Philad. **33**:230-232.

———1922—List of the Robberflies (Asilidae) of N. Carolina. Entom. News, etc. Philad. **33**:294-298.

———1923—Additional Records of Lepidoptera from N. Carolina. Entom. News, etc. Philad. **34**:113-118.

———1923—Additional Surphidae (Diptera) from N. Carolina, with descriptions of two supposed new species. Entom. News, etc. Philad. **34**:277-279.

———1924—Three supposed new species of *Ceraturgus* (Diptera) from N. Carolina. Entom. News, etc. Philad. **35**:8-12.

BROWN, FRANK R., AND J. W. PEARSON. 1938—Some *Culicidae* of the Reelfoot Lake region. Jour. Tenn. Acad. Sci. **13**(2):126-132. April.*

BUTLER, H. G. 1931—Observations on the Biology of the Peach Borer in Roane County, Tennessee. (Harriman, Tenn. 1930) Jour. Econ. Entom. **24**(4):851-854.

———1931—Peach Insects of Tennessee. Tenn. State Hort. Soc. Proc. **23**:42-45.

———1932—Observations on the Biology of the Peach Borer in Roane County, Tennessee. (Harriman, Tenn. 1931) Jour. Econ. Entom. **25**(4):781-786.

———1933—Larval Parasites of the Oriental Fruit Moth in Roane County, Tennessee. Jour. Econ. Entom. **26**(5):982-987.

BYERS, C. F. 1931—Dixie Dragonflies collected during the summer of 1930. (Odonata). Entom. News, etc. Philad. **42**:(4):113-119.*

CARPENTER, F. M. 1931—Revision of the nearctic Mecoptera. (Neuroptera). Bull. Mus. Comp. Zool. Harvard Coll. **72**(6):205-277. 8 pls. 6 figs. Inc. *Panorpa longicornis; P. isolata;* and *P. acuta*, from Tenn.

———1933—Trichoptera from the mountains of North Carolina and Tennessee. Psyche **40**(1):32-47. 2 pls. 1 fig. A report on 23 species.

CHAMBERLIN, RALPH V. 1911—The Lithobiomorpha of the Southeastern States. Annals Entom. Soc. Amer. **4**:32.*

———1912—The Geophilodea of the Southeastern States. Bull. Mus. Comp. Zool. Harvard Coll. **54**(13):407-436. April. 3 pls.

CHAMBERS, V. T. 1870—Time of appearance of the Polyphemus Moth in Louisiana and Kentucky. Amer. Entom. **2**:156.

COLCORD, M. AND E. P. FELT. 1921—Index II, to the Literature of American Economic Entomology. 1915-1919. Amer. Assn. Econ. Entom. Melrose Highlands, Mass. 1-388.* Inc. here because of general interest.

COLE, A. C., JR. 1938—Suggestions concerning taxonomic nomenclature of the Hymenopterous family Formicidae, and descriptions of three new Ants. Amer. Midl. Nat. **19**(1):236-241. *Leptothorax tennesseensis*, n. sp. and *Aphaenogaster texana punctithorax*, n. subsp. Gt. Smoky Mts., Tenn.

———1938—Insect Collecting in the Great Smoky Mountains National Park. Jour. Tenn. Acad. Sci. **13**(4):274-276. Oct.

CORLEY, N. 1937—Dytiscidae of the Nashville region. (Coleop.) Bound thesis. 1-68. Peabody Coll. Library. Nashville. August. Only 19 species are listed from 13 localities in central Tennessee.

COTTON, E. C. 1908—The Life History and Habits of the North American Fever Tick, with special reference to eradication. (in Tenn.) Bull. Agric. Exp. Sta. Univ. of Tenn. Knoxville. No. **81**:53-71. Dec.

——— AND J. F. VOORHEES. 1911—The Cattle Tick as affected by climate. (in Tenn.) Bull. Agric. Exp. Sta. Univ. of Tenn. Knoxville No. **94**:119-164.

CURRAN, C. HOWARD. 1926-1927—The nearctic species of the genus *Rhaphium* Meigen. (Dolichopodidae: Diptera). Trans. Royal Canadian Inst. **15**(34) II. : 249-260, 1926. **16**(35) I. 99-179. 1927. Lists R. *simplicipes* for Tenn.

CUSHMAN, R. A. 1935—New Ichneumon-Flies. Jour. Wash. Acad. Sci. **25**(12): 547-564. 1 fig.

DARLINGTON, P. J., JR. 1931—On some Carabidae, including new species, from the mountains of N. Carolina and Tennessee. (Coleop.) Psyche **38**(4):145-164. *Scaphinotus viduus irregularis; S. confusus; Nomaretus unistriatus; Sphaeroderus multicarinatus; Nebria appalachia; Pterostichus unicarum; P. sphodrinus; P. primus*, and *P. carolinus fumorum*, from Tennessee.

———1933—The subspecies of *Sphaeroderus canadensis* Chd. (Coleop.) Psyche **40**(2):62-64. *S. canadensis*, ssp. *lengi* from N. C.-Tenn. state line. East Tennessee.

DAVIDSON, R. H. AND D. M. DELONG. 1938—Studies of the genus *Empoasca*. (Homoptera: Cicadellidae). V. Twelve new species of *Empoasca*. Ohio Jour. Sci. **38**(2):90-96. March. *E. decurvata*, n. sp. and *E. excava*, n. sp. from Clarksville, Tenn.

DAVIS, W. T. 1910—Miscellaneous notes on collecting in Georgia. Jour. Entom. Soc. N. Y. **18**:82-85.

———1913—*Williamsonia*, a new genus of Dragonflies from N. America. Bull. Entom. Soc. Brooklyn **8**:93-96.

———1914—A new species of *Atlanticus* (Orthoptera) from the mountains of Georgia and N. Carolina. Bull. Entom. Soc. Brooklyn **9**:104-106.

———1918—Mississippi Cicadas, with a key to the species of the Southeastern U. S. Jour. Entom. Soc. N. Y. **26**:141-155.*

DELONG, D. M. 1916—The Leafhoppers, of Jassoidea of Tennessee. Tenn. State Bd. of Entom. Bull. **17**.* Rare. 212 species and varieties are listed.

———1918—Additional Record of Tennessee Cicadellidae. (Hemiptera: Homoptera). Ohio Jour. Sci. **18**(7):233-242. May.* Lists *Macropsis occidentalis; M. tristis; Draeculacephala angulifera; Gypona* sp.; *G. scarlatina; G. spadix*, n. sp.; *Aligia modesta; Deltocephalus alboneura*, n. sp.; *Thamnotettix proprius*, n. sp.; *Alebra bicincta; A. albostriella*, and *A. eburnda*, from Clarksville, Tenn.

———1918—Additional Records of Tennessee Cicadellidae. Ohio Nat. **18**:228.*

———1926—Three new species of Cicadellidae previously confused with related species. Trans. Entom. Soc. Amer. **52**(2):89-92. *Thamnotettix arundineus;* Tenn.

——— AND R. H. DAVIDSON. 1933—Some new species of *Eugnathodus*. (Homoptera: Cicadellidae). Ohio Jour. Sci. **33**(1):55-58. *E. neglecta* var. *pallida*, from Tenn.

———1935—A new genus and five new species of Leaf-hoppers related to *Thamnotettix*. (Homoptera: Cicadellidae). Entom. News, etc. Philad. **46**:180-183. July. *Arundanus marginellus*, n. sp. from Tenn.

——— AND R. H. DAVIDSON. 1935—Some new N. American species of deltocephaloid Leafhoppers. Canadian Entom. **67**(8):164-172. 1 pl. *Polyamia similaris*, from Tenn.

——— AND C. O. MOHR. 1936—Studies of the genus *Scaphoideus*. (Homoptera: Cicadellidae) I. Seventeen new N. American species. Amer. Midl. Nat. **17**: 965-977. *S. immistus*, *S. flexus*, and *S. brevidens*, from Tenn.

———1937—The genera *Cyperana* and *Paluda* in North America. Amer. Midl. Nat. **18**(2):225-236. March. Inc. *C. melanogaster* (Provancher) from Tenn.

——— AND C. O. MOHR. 1937—The genus *Graminella*. (Homoptera: Cicadellidae). Amer. Midl. Nat. **18**:622-630. With pls. Lists *G. fitchii*, from Tenn.

———1938—The Genus Phlepsius—A Study of the North American Species with Special Reference to the Characters of the Male Genitalia. Lloydia (Cincinnati) **1**(1-4):232-252, 8 pls. *Phlepsius abruptus*, n.sp. from Bells, Tenn.

DENNIS, C. A. 1938—The Distribution of Ant species in Tennessee, with reference to Ecological Factors. Annals Entom. Soc. America **31**(2):267-308.* A useful reference.

DICKERSON, E. L. AND H. B. WEISS. 1917—The Azalea Lace-Bug, *Stephanitis pyrioides* Scott. Entom. News, etc. Philad. **28**:101-105. Tennessee.

DOZIER, H. L. 1922—An annotated List of Mississippi Chrysomelidae. (Coleop.) Ohio Jour. Sci. **22**(4):117-124. Feb.* 125 species are listed.

——— 1928—The Fulgoridae or plant-hoppers of Mississippi, including those of possible occurrence. A taxonomic, biological, ecological, and economic study. Tech. Bull. Miss. Agric. Exp. Sta. **14**:1-152.*

DRAKE, CARL J. 1916—A new Tingid from Tennessee. (Hemiptera). Ohio Jour. Sci. **16**(7):326-328. *Leptostyla costofasciata*, n. sp. from Clarksville, Tenn.

———, AND H. M. HARRIS. 1926—Notes on American Anthocoridae, with descriptions of new forms. Proc. Biol. Soc. Washington. **39**:33-45. Inc. *Lasiochilus fusculus*, from Miss. and Tenn.

——— ———1928—Concerning some North American Water-Striders with descriptions of three new species. Ohio Jour. Sci. **28**(5):269-276. *Gerris nebularis; G. insperatus; G. marginatus; Rheumatobates tenuipes; R. trulliger; Microvelia fontinalis*, and *M. austrina*, are mentioned from Tenn.

DYAR, H. G. 1922—The Mosquitoes of the U. S. Proc. U. S. Natl. Mus. **62**:1-119.* *Culex erraticus; C. peccator; C. quinquefasciatus; Psorophora sayi; P. horridus; P. columbiae; Aëdes hirsuteron; A. triseriatus; A. vexans; A. aegypti; Megarhinus septentrionalis;* and *Anopheles quadrimaculatus*, recorded from Tenn.

FERNALD, H. T. 1928—Insects; the People and the State. Sci. Monthly **27**:193-205. Address to Amer. Assn. of Econ. Entom. Nashville, Tenn. Dec., 1927.

GILMORE, J. U. AND J. MILAM. 1934—A new Pest in Tobacco Plant Beds, *Limnobia ultima*. Jour. Econ. Entom. **27**:290-291. Larvae attacking seedlings in Tenn. Control with freshly-mixed $KMn0_4$ (4 gm./gal.) or with nicotine sulphate (10 cc./gal.).

———1938—Observations on the Hornworms attacking Tobacco in Tennessee and Kentucky. Jour. Econ. Entom. **31**(6):706-712. Summary of years observations on *Protoparce sexta* and *P. quinquemaculata*.

GLOYD, LEONORA K. 1936—Three new North American species of Gomphinae. (Odonata). Occ. Papers, Mus. Zool. Univ. of Mich. **326**:1-18. 3 pls. Feb. 25. *Gomphus rogersi*, from Long Cr., Fentress Co., Tenn.

GREEN, SUSIE C. 1937—Aquatic Hemiptera of Reelfoot Lake. (Tenn.) Jour. Tenn. Acad. Sci. **12**(1):154. Jan. Contrib. no. 10, Reelfoot Lake Biol. Sta. A list of 29 species.

GROTE, A. R. 1871—Descriptions of Lepidoptera from Alabama. Canadian Entom. **3**:101. 124. 181.

HANCOCK, J. L. 1918—A new genus and two new species of Tettigids (Orthoptera), with a note on *Nomotettix borealis* Walker. Entom. News, etc. Philad. **29**(9):343. Nov. Clarksville.

HEBARD, MORGAN. 1919—Remarks on the species assigned to *Cavotettix* Hancock, a synonym of *Neotettix* Hancock. Entom. News, etc. Philad. **30**:78-82. March. *Neotettix proavus*, from Clarksville, Tenn.

———1934—Studies on Orthoptera which occur in North America north of the Mexican boundary. III. Revisionary data and new N. American Decticinae. Trans. Amer. Entom. Soc. **60**(1):31-55. 2pls. 1 fig.* Mentions *Atlanticus americana* ssp. *hesperus*, from Tenn.

———1934—New genera and species of the *Melanopi* found within the U. S. and Canada. (Orthop.) V. VI. Trans. Amer. Entom. Soc. **60**:337-390. Inc. *Melanoplus hubbelli* from Tenn.

HINE, JAMES S. 1902—New or little-known Diptera. Ohio Nat. **2**(5):228-230. March. Inc. *Criorhina umbratilis* Will, from Nashville, Tenn.

HOOKER, W. A. 1909—The Geographical Distribution of Americaan Ticks. Jour. Econ. Entom. **2**:403. Dec. For Tennessee, see p. 408.

HOWE, R. W. 1916—Studies of the Mexican Cotton Boll Weevil in the Mississippi Valley. U. S. D. A. Bull. **358**:1-32.

HUBBELL, T. H. 1926—Correction of records of *Ceuthophilus* (Orthop.: Tettigoniidae). Florida Entom. **10**(1):14. Refers to Tennessee records.

———1936—A Monographic Revision of the genus *Ceuthophilus*. Univ. of Florida Publ. Biol. series **2**(1):1-551. 38 pls.* Refers to many Tennessee species and localities: 112-114, 154, 165, 183, 192, 238, 313, 350, 369, 442.

HULL, FRANK M. 1922—New Syrphidae (Diptera) from Mississippi. Annals Entom. Soc. Amer. **15**:370-373.

———1924—Milesia in North America. (Diptera). Entom. News, etc. Philad. **35**:280. For Tenn: 282.

HUNGERFORD, H. B. 1928—Some Corixidae from Northern States and Canada. (Hemiptera). Canadian Entom. **60**(9):226-230. 1 pl. includes *Arctocorixa hubbelli*, from Tenn.

HUTCHINS, R. E. 1933—Annotated List of Mississippi Rhopalocera. (Lepidop.) Canadian Entom. **65**:210.

HUTSON, RAY, ET. AL. 1933—Scientific Notes. Jour. Econ. Entom. **26**(1):291-304. 1 fig. Note on outbreak of grasshoppers in Tennessee during 1932.

IVES, J. D. 1934—Notes on the Fauna and Ecology of Tennessee Caves. Jour. Tenn. Acad. Sci. **9**(2): 149-153. 1 fig.* *Limosina* sp. (Diptera) taken 1700 ft. from entrance of Indian Cave. Development studied. *Meta menardii* (Aran.), *Ivesia tennesseensis*, *Machilis variabilis* (Thysanura) taken from caves.

———1938—Cave Hibernation of Mosquitoes. Jour. Tenn. Acad. Sci. **13**(1):15-20. Jan.* Lists hibernation data for Tenn. caves, with obs. on temp. and humidity conditions. Buttry's Cave, Three Springs, Tenn.

JEWETT, H. H. 1924—The Grape Leaf-Hoppers of Bluegrass Kentucky. Bull. Ky. Ky. Agric. Exp. Sta. **254**:1-130.*

JOHNSON, H. A. 1937—Attractivity of Light for Anopheles Mosquitoes. Jour. Tenn. Acad. Sci. **12**(1):104.

KEARFOTT, W. D. 1907—Microlepidoptera from the Black Mountain region of North Carolina, with descriptions of new species. Bull. Amer. Mus. Nat. Hist. N. Y. **23**(8):153-169. Gives a list of 11 species.

KENNEDY, C. H. AND M. M. SCHRAMM. 1933—A new *Strumigenys* with notes on Ohio species. (Formicidae: Hymenopt.) Annals Entom. Soc. Amer. **26**(1):94-104. *S. dietrichi* reported from Ill. and Tenn.

KINSEY, ALFRED G. 1929—The Gall-Wasp genus *Cynips*, a study in the origin of species. Indiana Univ. Studies **16**(84-86). June-Sept. (Pub. Feb. 27, 1930). Gives species from Tenn. and adjacent regions.

KIRBY, W. F. 1906—A Synomyic Catalogue of Orthoptera. II. Orthoptera Saltatoria. (I) (Achetidae et Phasgonuridae). British Mus. London 1-562. Mentions Tenn. species.

KNIGHT, HARRY H. 1927—Notes on the Distribution and Host Plants of some North American Miridae. (Hemiptera). Canadian Entom. **59**(2):34-44.* Accumulated notes from the author's work in collecting and naming Miridae for ten years. For Tenn.: *Leucopoecila albofasciata* Reut.; *Halicotoma valida; Fulvius imbecilus* Say; *Lopidea davisi* Knight; *Platytylellus atripennis* Reut., and others from the southeastern States.

KNULL, J. N. 1930—Notes on Coleoptera. No. 2. Entom. News, etc. Philad. **41**: 82-86. March. Mentions *Chrysobothris orono* Frost, from Tenn.

KOEN, JOHN. 1937—The Dragonflies of the Reelfoot Lake Area. Jour. Tenn. Acad. Sci. **12**(1):129-153. Jan.* A list of 31 species, with descriptive notes and tables.

LANGSTON, J. M. 1927—Phyllophaga of Mississippi. Tech. Bull. Miss. Agric. Exp. Sta. **15**:1-103. 13 pls.*

LENG, C. W. 1910—Notes on Coleoptera collected in Northern Georgia. Jour. Entom. Soc. N. Y. **18**:71-82.

LUTZ, F. E. AND T. D. A. COCKERELL. 1920—Notes on the Distribution and Bibliography of N. American Bees of the families Aphidae, Meliponidae, Bombidae, Euglossidae, and Anthophoridae. Bull. Amer. Mus. Nat. Hist. **42**(15):491-641.* *Bombus* and *Psithyrus* from Tenn.

MARCOVICTCH, S. 1920—Grasshoppers of Tennessee. Tenn. State Bd. of Entom. Bull. 33. **9**(2):1-112.* A useful and important reference, but rare.

———1923—A root weevil (*Stephanocleonus plumbeus* Lec.) reared from strawberry. Canadian Entom. **55**:218. Locality: Tennessee.

———1925—The Strawberry Root Louse in Tennessee. Jour. Agric. Res. **30**(5): 44-49.

——— AND S. A. ROBERT. 1925—The Corn Ear Worm on Tomato. U. S. D. A. Tenn. Sta. Bull. No. 133:3-14.

———1926—The control of the Striped Cucumber Beetle. (in Tenn.) Agric. Exp. Sta. Univ. of Tenn. Knoxville. Circ. no. 1. 2 pp. Feb.

——— AND W. W. STANLEY. 1930—The climatic limitations of the Mexican Bean Beetle. Annals Entom. Soc. Amer. **23**(4):666-686. Dec. With special ref. to Tenn. localities and conditions.

———1930—How to prevent damage by the Mexican Bean Beetle Tenn. Agric. Exp. Sta. Univ. of Tenn. Knoxville. Circ. no. 28. 2 pp. With special reference to Tenn.

———1934—Control of Weevils in stored Beans and Cowpeas. Tenn. Agric. Exp. Sta. Univ. of Tenn. Knoxville. Bull. no. 150:1-8. (Tenn. conditions).

———1934—The Wooly Apple Aphid in Tennessee. Tenn. Agric. Exp. Sta. Univ. of Tenn. Knoxville Bull. **151**:1-16.

———1934—The Wooly Aphis in Tennessee. Jour. Econ. Entom. **27**(4):779-784.

———1936—Studies of the Ecology and Control of Cutworms in Tennessee. Tenn. Agric. Exp. Sta. Univ. of Tenn. Knoxville Bull. **159**:1-16. Oct.*

——— AND W. W. STANLEY. 1937—Control of Tobacco Insects in Tennessee. Tenn. Agric. Exp. Sta. Univ. of Tenn. Knoxville Bull. **160**:1-14. Jan.*

MARSTON, L. C., JR. 1931—*Dynastes tityus* Linn. in Delaware. (Coleop.) Entom. News, etc. Philad. **42**:28. Jan. Also reported from Knoxville, Tenn.

MCATEE, W. L. AND J. R. MALLOCH. 1933—Revision of the subfamily Thyreocorinae of the Pentatomidae. (Hemipt. Annals Carnegie Mus. **21**(4):191-411. 14 pls.* Mentions *Galgupha carinata*, from Tenn.

MELENEY, H. E. AND E. L. BISHOP. 1929—Observations on the Malaria problem of West Tennessee. Southern Med. Jour. **22**:382. Apr.

———, ———, AND F. L. ROBERTS. 1930—Further Observations on the Malaria problem of West Tennessee. Southern Med. Jour. **23**(5):435-442.

——— AND JAMES CRABTREE. 1934—Results from screening of rural homes in Lake County, Tennessee. Southern Med. Jour. **27**(6):552-558. June.

———1937—The Problem of Malaria Mortality in the U. S. Amer. Jour. Trop. Med. **17**(1):15-24. Jan. Refers to Tennessee conditions and statistics.

METCALF, Z. P. 1915—A List of Homoptera of N. Carolina. Jour. E. Mitchell Sci. Soc. **31**:35-60.*

MORGAN, H. A. 1905—Texas Cattle Fever Tick: Pasture methods of Eradication. Tenn. Agric. Exp. Sta. Univ. of Tenn. Knoxville. Bull. **18**(1):1-10. Jan. *Boophilus annulatus* in Tenn.

MORGAN, A. C. 1911—Tobacco Insects of Tennessee. Tenn. Agric. Exp. Sta. Univ. of Tenn. Knoxville Bull. **93**:101-113. June.*

——— AND J. U. GILMORE. 1924—The Tobacco Flea-Beetle in the dark-fired tobacco district of Kentucky and Tennessee. U. S. D. A. Farmer's Bull. No. 1425. 1-12.*

MORSE, A. P. 1904—New Acrididae from the Southeastern States. (Orthop.) Psyche **11**:7-13. *Eotettix pusillus* from N. Carolina.

MOULTON, DUDLEY. 1929—Contribution to our knowledge of American Thysanoptera. Bull. Entom. Soc. Brooklyn **24**(4):224-244. 1 fig. *Cephalothrips elegans;* Tenn.

MUESEBECK, C. F. W. 1932—Revision of the Nearctic Ichneumon-Flies belonging to the genus *Macrocentrus*. Proc. U. S. Natl. Mus. **80**(23):1-55. Inc. *M. instabilis;* Tenn.

MULLENS, N. E. 1937—Taxonomy and Morphology of the Hydrophilidae of the Nashville region. (Coleop.) Bound thesis. 1-60. Peabody Coll. Library. Nashville. June.* Only 13 species are described from 14 stations in the Nashville region.

MUSGRAVE, PAUL N. 1932—Notes on Helmidae (Coleop.) taken in the Tennessee Great Smoky Mountains, with descriptions of new species. Proc. Entom. Soc. Washington **34**(5):78-81. 1 pl.* Notes on 5 subspecies of *Limnius cryophilus*, a type in the U. S. Natl. Mus.

NEEDHAM, J. G. AND H. B. HEYWOOD. 1929—Handbook of the Dragonfles of North America. Thomas. Springfield and Baltimore. 1-378.* Contains Tenn. references.

———, J. R. TRAVER, AND Y.-C. HSU. 1935—The Biology of Mayflies, with a Systematic Account of North American Species. Ithaca, N. Y. 1-759. Many pls. and figs.* For Tenn. see pp. 245, 258, 264, 283, 309, 318, 343, 353, 489, 550, 588, 594, 610.

OSBORN, HERBERT, AND CARL J. DRAKE. 1916—Some new species of nearctic Tingidae. Ohio Jour. Sci. **17**(1):9-15. *Corythucha associata*, Clarksville, Tenn.

——— ——— 1917—Notes on American Tingidae, with descriptions of new species. Ohio Jour. Sci. **17**(8):295-307. 4 Tenn. species mentioned

OSBURN, WILLIAM. 1895—Rhopalocera of Tennessee. (Lepidop.) Entom. News, etc. Philad. **6**(8):245-248.

———1895—Rhopalocera of Tennessee. Pt. II. Entom. News, etc. Philad. **6**(9): 281-284.

PELTON, W. C. 1933—Control of Garden Insects. Tenn. Agric. Exp. Sta. Univ. of Tenn. Knoxville Pub. **176**: 2pp. April.* Refers particularly to Tennessee conditions.

POOS, F. W. 1933—Four new species of *Empoasca*. (Homop: Cicadellidae). Proc. Entom. Soc. Washington. **35**(8):174-179. 1 pl. *E. sativae* and *E. curvata*, from Tenn.

REINHARD, H. J. 1930—A Synopsis of the genus *Macromeigenia*, including the description of one new species. (Diptera). Entom. News, etc. Philad. **41**:261. Oct. Tenn.; p. 262.

RICHARDS, A. GLENN, JR. 1931—Noctuidae of Northern Georgia and Tennessee. (Lepidop.) Entom. News, etc. Philad. **42**(9):247-252. (10):271-276. Lists species collected at Athens, Ga. and Monteagle, Tenn.

———1931—Distributional Studies on Southeastern Rhopalocera. (Macrolepidop.) Bull. Entom. Soc. Brooklyn **26**(5):234-255.* Districts in Ga., Tenn., N. C., S. C., with 127 species.

ROGERS, J. SPEED. 1930—The Summer Crane-Fly Fauna of the Cumberland Plateau in Tennessee. Occ. Papers, Mus. Zool. Univ. of Mich. **215**:1-50. 5 pls. August 15.* One of the few papers on the fauna of the particular area. A description of the territory with a large list of species.

ROHWER, S. A. 1934—Descriptions of five parasitic Hymenoptera. Proc. Entom. Soc. Washington **36**(2):43-48. Inc. *Anthonomus signatus* and *Phanerotoma formosana* from Tennessee.

SCHAEFFER, CHARLES. 1932—Notes on some Galerucinae, with descriptions of new species. (Coleop.: Chrysomelidae). Canadian Entom. **64**(10):236-239. Lists *Phyllobrotica stenidea*, from Tenn.

SCHAUPP, F. G. 1881—List of the described Coleopterous larvae of the U. S., with some remarks on their classification. Bull. Entom. Soc. Brooklyn **2**:1-3, 9, 10, 21, 22, 29, 30. **3**:64, 90, 94, 100. **4**:8, 15, 16, 24, 31, 32, 36, 46.

SCUDDER, S. H. 1880—The Entomological Libraries of the U. S. Library of Harvard Coll. Bibliog. contrib. 11. Cambridge. 8vo. 1-6.

———1894—The North American *Ceuthophili*. Proc. Amer. Acad. Arts. & Sci. **30**:17-111. *Ceuthophilus ensifer* Packard from Nickajack Cave, Tenn.

———1900—Catalogue of the described Orthoptera of the U. S. and Canada, with an appendix of descriptions of new species. Proc. Davenport Acad. Sci. **8**:1-104. 3 pls.* Mentions Tennessee species.

SHERMAN, F., JR. 1908—Notes on tiger beetles and elevations. Entom. News, etc. Philad. **19**:360-362. Consideration of localities in N. Carolina.

SHIELDS, S. E. 1938—Tennessee Volley Mosquito Collections. Jour. Econ. Entom. **31**(3):426-430.* Species collected in the Tenn. Valley, 1934-1936: *Anopheles punctipennis; A. crucians; A. quadrimaculatus; A. barberi; A. walkeri; Aëdes dupreei; A. hirsuteron; A. thibaulti; A. canadensis; A. atropalus; A. triseriatus; A. vexans; A. aegypti; Culex peccator; C. inhibitator; C. salinarius; C. restuans; C. quinquefasciatus; C. pipiens; C. apicalis; Theobaldia melanura; T. inornata; Psorophora howardi; P. ciliata; P. ferox; P. varipes; P. cyanescens; P. discolor; P. columbiae; P. signipennis; Mansonia perturbans; Uranotaemia sapphirina; Orthopodomyia alba; O. signifera; Megarhinus septentrionalis.*

SKINNER, HENRY. 1907—The Identity of *Thecla calanus* and *edwardsi*. (Lepidop.) Entom. News, etc. Philad. **18**(2):47-48. Feb. *T. calanus*, Nashville, Tenn.

SMITH, JOHN B. 1888—Notes on the species *Lachnosterna* of temperate North America, with descriptions of new species. Proc. U. S. Natl. Mus. **11**:481-525. *L. ulkei* and *L. hornii;* from Tenn.

———1911—Notes on the species of *Acronycta*, and descriptions of new species. Entom. News, etc. Philad. **22**:309-318. July. *A. tristis*, n. sp. from Johnson City.

SMITH, M. R 1924—An annotated List of the Ants of Mississippi. Entom. News, etc. Philad. **35**:47, 54, 77-85, 121-127.

———1927—An additional annotated List of the Ants of Mississippi. Entom. News, etc. Philad. **38**:308-314.

———1928—An additional annotated List of the Ants of Mississippi, with a description of a new species of *Aphaenogaster*. Entom. News, etc. Philad. **39**:242-246. 257-279.

———1931—An additional annotated List of the Ants of Mississippi. Entom. News, etc. Philad. **42**:16-24. **43**:157-160.

STANLEY, W. W. 1936—Studies of the Ecology and Control of Cutworms in Tennessee. Tenn. Agric. Exp. Sta. Univ. of Tenn. Knoxville Bull. **159**:1-16. Oct.*

SUMMERS, H. E. 1891—The true Bugs, or Heteroptera, of Tennessee. Tenn. Agric. Exp. Sta. Univ. of Tenn. Knoxville Bull. **9**:3. July.*

THOMAS, C. 1873—The Acrididae of the U. S. Hayden's Report of the U. S. G. S. of the Territories. 4to. 1-258. Washington. *Pyrgomorpha punctipennis*, from East Tenn. 68.

TOWNES, H. K., JR. 1938—The Nearctic Species of Netelia (Paniscus of Authors) and a Review of the Genera of Neteliini (Hymenoptera, Ichneumonidae). Lloydia (Cincinnati) **1**(1-4):168-231, 8 pls. Nine spp., four of these new, are listed from North Carolina, mostly from Raleigh.

TRAVER, JAY R. 1932—Mayflies of N. Carolina. Jour. E. Mitchell Sci. Soc. **47**(1): 85-161. (2):163-236.

———1933—Heptagenine Mayflies of North America. Jour. Entom. Soc. N. Y. **41**:105-125. Inc. N. C. and Tenn. species.

———1934—New North American species of Mayflies. Jour. E. Mitchell Sci. Soc. **50**:189-254. Dec. *Isonychia diversa;* from Tenn.

VALENTINE, J. MANSON. 1931—New cavernicole Carabidae of the subfamily Trechinae Jeannel. Jour. E. Mitchell Sci. Soc. **46**(2):247-258. 3 pls. Collections from limestone caves in Va., W. Va. Tenn. and Ala.

———1932—A Classification of the genus *Pseudanophthalmus* Jeannel (Fam. Carabidae) with descriptions of new species and notes on distribution. Jour. E. Mitchell Sci. Soc. **47**(2):261-280. 8 pls.* *P. alabamae*, from Tenn.

———1935—Speciation in *Steniridia*, a group of cychrine beetles. (Fam. Carabidae, gen. *Scaphinotus*). Jour. E. Mitchell Sci. Soc. **51**(2):341-375. 9 pls.* *S. andrewsi parvitarsalis*, Ga., N. C., Tenn.; *S. andrewsi darlington*, Tenn. and N. C.; *S. andrewsi waldensia*, Tenn.

WALKER, E. M. 1912—N. American Dragonflies of the genus *Aeschna*. Univ. of Toronto Studies. Biol. series. No. 11. 1912. (See Wright, 1938).

WATSON, J. R. 1933—Some Thysanoptera of the Great Smoky Mountains. Florida Entom. **16**(4):61-62. Data on 11 species. *Ctenothrips frosti* and *Trachythrips watsoni*, new to Tenn., Ga., and S. Carolina.

———1933—Two new species of *Plectrothrips*. Florida Entom. **17**(1):16-18. 1 pl. (2):33-34. Mentions *P. montanus;* from Tenn. 16.

WESSON, L. G. 1935—A new species of Ant from Tennessee. Entom. News, etc. Philad. **46**:208-210. *Leptothorax (Dichothorax) manni*, n. sp. from Nashville.

WHEELER, W. M. 1904—The Ants of North Carolina. Bull. Amer. Mus. Nat. Hist. N. Y. **20**(26):299-306.

WILLIAMSON, E. B. 1901—The subgenus *Stylurus* Needham, Sely's groups VI and VII of the genus *Gomphus*, and on the post-anal cells in the latter. Trans. Entom. Soc. Amer. **27**:205-217. Lists Tenn. species. See Wright, 1938.

———1903—A new species of *Gomphus* related to *G. fraternus*. Entom. News, etc. Philad. **13**:47-49. From the Cumberland River, Nashville, Tenn. *G. hybridus* from mouth of Stone's River, Tenn.

———1903—The Dragonflies of Tennessee, with a few records for Virginia and Alabama. Entom. News, etc. Philad. **14**:221-229. See Wright (1938) for species list.

———1909—The N. American Dragonflies (Odonata) of the genus *Macromia*. Proc. U. S. Natl. Mus. **37**:369-398. 2 pls. Dec. 14.* Species from Knoxville, Big Creek, Sneedsville, Clinch River, Tenn.

———1912—*Hetaerina titia* and *tricolor*. (Odonata) Entom. News, etc. Philad. **23**: 98-101. From Nashville and the Clinch River, Tenn.

———1912—The Dragonfly *Argia moesta*, and a new species. Entom. News, etc. Philad. **23**:196-203. Cumberland River at Nashville, Tenn.

———1914—*Gomphus pallidus* and two related species. (Odonata). Entom. News, etc. Philad. **25**:49. Feb. See p. 54.

———1923—Odonatological Results of an auto trip across Indiana, Kentucky, and Tennessee. Entom. News, etc. Philad. **34**(1):6. Jan. (2):37. Feb.*

———1934—Dragonflies collected in Kentucky, Tennessee, N. and S. Carolina, and Georgia, in 1931. Occ. Papers, Mus. Zool. Univ. of Mich. **288**:1-20. June 26.* See Wright, 1938.

WILSON, C. B. 1907—The Dragonflies of the Mississippi Valley, collected during the Pearl Mussel investigations on the Mississippi River, July and August, 1907. Pub. no. 1692. Proc. U. S. Natl. Mus. **36**:653-671. West Tennessee.

———1912—Dragonflies of the Cumberland Valley in Kentucky and Tennessee. Pub. no. 1928. Proc. U. S. Natl. Mus. **43**:189-200.* See Wright (1938).

WRIGHT, MIKE. 1937—A Survey of the nymphs of the order Odonata in the vicinity of Nashville, Tennessee. Bound thesis. 1-64. 4 pls. Vanderbilt Univ. Library. Nashville. 75 adult species, 25 species of nymphs are listed.

———1938—A Review of the Literature on the Odonata of Tennessee. Jour. Tenn. Acad. Sci. **13**(1):26-33. Jan.* A review of all papers, listing species and their localities in Tennessee. 75 species are recorded.

———1938—Notes on the Dragonflies of Reelfoot Lake, Tennessee. Jour. Tenn. Acad. Sci. **13**(2):104-108. April. Contrib. no. 14, Reelfoot Lake Biol. Sta.* Information on *Gomphus pallidus; Dromogomphus spoliatus; Libellula pulchella; Enallagma vesperum; Libellula luctosa; Lestes inequalis; L. rectangularis; Argia apicales; Enallagma signatum; E. exsulans,* and *Ischnura posita.*

Part 8. Pisces

AGASSIZ, L. 1854—Notice of a collection of Fishes from the Southern Bend of the Tennessee River, Alabama. Amer. Jour. Sci. & Art **17** Ser. 2.: 297-308. 353-369.

BAKER, C. L. 1937—The Commercial, Game, and Rough Fishes of Reelfoot Lake. Jour. Tenn. Acad. Sci. **12**(1):9-59. Jan.* Contrib. no. 1. Reelfoot Lake Biol. Sta. With many pls. and figs

——— AND M. V. PARKER. 1938—The Fishes of Reelfoot Lake. Jour. Tenn. Acad. Sci. **13**(2):160-163. April.* A list of 56 species from the region.

———1939—Additional Fishes of Reelfoot Lake. Jour. Tenn. Acad. Sci. **14**(1):6-40. Jan. *Report Reelfoot Lake Biol. Sta. **3**. Contrib. no. 20. Account of many species, with annotations and references. Many pls.

———1939—Key to Reelfoot Lake Fishes. Jour. Tenn. Acad. Sci. **14**(1):41-45. Jan. Report Reelfoot Lake Biol. Sta. **3**.*

BALL, M. 1937—Minnows of the Nashville region. Bound thesis. 1-78. Peabody Coll. Library. Nashville. August.

BEAN, B. A. 1903—Notice of a collection of Fishes made by H. H. Brimley in Cane River and Bollings Creek, N. Carolina, with a description of a new species of *Notropis.* Proc. U. S. Natl. Mus. **26**:913-914. *N. brimleyi,* with others.

BOEPPLE, J. F. 1911—Notes on the Fish of the Cumberland River. Trans. Amer. Fisheries Soc. 181-182.* (pub. 1912)

BURROWS, R. JR. 1935—A Biological Survey of Streams in the Great Smoky Mountains National Park. Dept. of Comm. Bur. of Fisheries. Washington (Mimeographed report)*

CARPENTER, S. J. 1931—The Circulation of the Blood in the swim bladder of some common Fishes of Eastern Tennessee. Bound thesis. Univ. of Tenn. Library. Knoxville.

CLIMAX (Pseudonym) 1880—Some interesting Facts about Fish in Tennessee Waters. Chicago Field. **13**:252.

———1880—Interesting Facts about Fish in the Harpeth River (Tenn.) and the tributaries. Chicago Field. **13**:304-305.

———1880—German Carp in Tennessee Chicago Field. **14**:263.

COPE, E. D. 1867—On the genera of Fresh-Water Fishes *Hypsilepis* Baird and *Photogenis* Cope, their species and distribution. Proc. Acad. Nat. Sci. Philad. 156-166. In this paper are recorded *H. cornutus; H. c. frontalis; H. coccogenis;*

H. galacturus; Photogenis leuciodus, and *P. telescopus*, now of the genus *Notropis*, from the Tenn. R. and tributaries of the Holston R.

———1870—On some Etheostomine Perch from Tennessee and N. Carolina. Proc. Amer. Philos. Soc. Philad. **11**:261-270. Jan. 7.* 11 species of fishes are recorded, now recognized as *Diplesion blennioides; Hypohomus aurantiacus; Percina caprodes; Etheostoma zonale; E. maculatum; E. camurum; E. vulneratum; E. rufilineatum; E. coeruleum; D. blennioides* (?), and *Ulocentra simoterum*, from the Tenn. and Cumberland Rivers. This is one of the few references including species from the Big South Fork of the Cumberland.

———1870—A Partial Synopsis of the Fishes of the Fresh Waters of North Carolina. Proc. Amer. Philos. Soc. Philad. **11**. Mentions *Ptychostomus erythurus*, from the French Broad River, Tenn.

———1871—Remarks on *Asteracanthus* Ag., from New Jersey, and *Labidesthes* Cope, from Tennessee. Proc. Amer. Philos. Soc. Philad. **11**:439-440.

Cox, Ulysses O. 1904—A Revision of the Cave Fishes of N. America. Report U. S. Fish Comm. 377-393.*

Evermann, B. W. and S. F. Hildebrand. 1914—Notes on the Fishes of East Tennessee. Doc. no. 832. Issued Sept. 21, 1916. Bull. Bur. Fisheries **34**:431-452. 13 figs.*

———1915-1916—The Fishes of Kentucky and Tennessee: A Distributional Catalog of the known species. Doc. no. 858. Issued Jan. 10, 1918. Bull. U. S. Bur. Fisheries **35**:293-368.* An important reference abstracting the papers to 1915.

Fowler, H. W. 1906—Some new and little-known Percoid Fishes. Proc. Acad. Nat. Sci. Philad. **58**:510-528. Dec.* *Ambloplites rupestris*, Cumberland R.; *Lepomis megalotis*, Coal Cr.; *L. palladus*, Coal Cr.; *Micropterus dolomieu*, Coal Cr.; *M. salmoides*, Coal Cr.; *Percina caprodes*, So. Fork, Cumberland R.; *Diplesion blennioides*, So. Fork, and Clinch R.; *Crystallaria asprella*, So. Fork, and *Etheostoma maculatum*, So. Fork. Not a modern list, but one of the few reporting species found in the Big South Fork of the Cumberland River in Tennessee.

———1907—Notes on Lancelets and Lampreys. Proc. Acad. Nat. Sci. Philad. **59**:461. *Ichthyomyzon bdellium* from the Clinch River, Tenn.

———1910—Notes on the variation of some species of the genus *Notropis*. Proc. Acad. Nat. Sci. Philad. **62**:273-293. April.* *N. procne longiceps; N. galacturus; N. telescopus*, from the Cumberland R. and Coal Cr., Tenn. *N. coccogenis; N. micropteryx*, from Coal Cr. *N. luciodus* from the Cumberland River.

———1922—Records of Fishes for the Eastern and Southern U. S. Proc. Acad. Nat. Sci. Philad. **74**:1-27. 2 pls.* Lists a large no. of species for N.C. and Ala. inc. *Lepisosteus punctatus; Notropis umbratilis*, and *Stizostedion canadense* from the Tenn. R.

———1923—Records of Fishes for the Southern States. Proc. Biol. Soc. Washington **36**:7-34. March 28.* Inc. *Ichthyomyzon bdellium*, Clinch River.

———1924—Notes on North American Cyprinoid Fishes. Proc. Acad. Nat. Sci. Philad. **76**:389-416.* *Semotilus atromaculatus*, So. Fork, Cumberland R.; *Rhinichthys atronasus*, Holston R., French Broad R.; *Leuciscus vandoisulus; Ceratichyths hyalinus*, and *Hybopsis kentuckiensis*, from Coal Cr., Tenn.

Gilbert, Charles H. 1887—Descriptions of new and little-known *Etheostomoids*. Proc. U. S. Natl. Mus. **10**:47-64.* *E. (Hadropterus) squamatus*, French Broad R.; *E. zonale; E. (Rhothoeca) blennius*, Tenn. R.; *E. saxatile*, Clinton, Tenn. *E. tuscumbia*, Tuscumbia, Ala. and *E. luteovinctum* from Stone's R., near Nashville.

———1889—Report on the Explorations during 1889, with notes on the Fishes of the Tennessee, Alabama, and Escambia Rivers. Bull. U. S. Fish Comm. Washington **9**:143-159.*

Gudger, E. W. 1930—*Ichthyomyzon concolor* in the Coosa R. at Rome, Ga., with notes on other lampreys in our South Atlantic and Gulf drainages. Copeia 145-147.*

H., J. D. 1879—Fish Protection in Tennessee. Forest & Stream **12**:131.

———1879—Tennessee Shad and Salmon. Forest & Stream **12**:185.

———1879—Success in Tennessee in Fish Protection. Forest & Stream **13**:826.

———1880—German Carp in Tennessee. Forest & Stream **13**:366.

———1880—Fish Culture and Protection in Tennessee. Forest & Stream **13**:1005.

HAY, O. P. 1880—On a collection of Fishes from Eastern Mississippi. Proc. U. S. Natl. Mus. **3**:488-515. List of 56 species, 15 being desc. as new.

———1883—On a collection of Fishes from the Lower Mississippi Valley. Bull. U. S. Fish Comm. **2**:57-75.

HAZZARD, A. S. 1932—Some Phases of the Life History of the Eastern Brook Trout, *Salvelinus fontinalis* Mitchell. Trans. Amer. Fisheries Soc. **62**:344-350. (Tenn.)

———1935—Low Water Temperature, a Limiting Factor in the successful production of Trout in Natural Waters. Trans. Amer. Fisheries Soc. **63**:204-207. Included here as an important reference for southern fisheries.

HENSHALL, JAMES A. 1889—On a collection of Fishes from East Tennessee. Jour. Cincinnati Soc. Nat. Hist. **12**(1):31-33. April.* *Campostoma anomalum; Chrosomus erythrogaster; Ulocentra simotera; Etheostoma coeruleum,* and *Cottus ictalops* from Whiteside, Tenn.

HILDEBRAND, S. F. 1932—On a collection of Fishes from the Tuckaseegee and upper Catawba River Basins, N. Carolina, with a descriptions of a new Darter. Jour. E. Mitchell Sci. Soc. **48**:50-82. 1 pl. 2 figs. *Poecilichthys gutselli,* n. sp. from the Tuckaseegee R., headwaters of Tenn. R.

HOWLAND, J. W. 1931—Studies on the Kentucky Black Bass, *Micropterus pseudaplites* Hubbs. Trans. Amer. Fisheries Soc. **61**:88-94. Also from Tenn.

HUBBS, CARL L. 1930—Material for a Revision of the Catostomid Fishes of Eastern North America. Misc. Publ., Mus. Zool. Univ. of Mich. **20**:1-47. April 30.* Important for a discussion of Tenn. distribution.

——— AND M. B. TRAUTMAN. 1937—Revision of the Lamprey genus *Ichthyomyzon.* Misc. Publ., Mus. Zool. Univ. of Mich. **35**. Reports *I. bdellium* from Clinch R. at Norris, Tenn. Coal Creek, Tenn. Saltville, Va. Madison Co., Ala.

——— AND R. W. ESCHMEYER. 1938—The Improvement of Lakes for Fishing, a method of Fish Management. Bull. no. 2, Inst. Fisheries Res. Univ. of Mich. 1-233. Inc. in this list because of general interest.

JORDAN, DAVID STARR AND A. W. BRAYTON. 1877—On *Lagochila,* a new genus of Catostomid Fishes. Proc. Acad. Nat. Sci. Philad. **29**:280-283. *L. lacera,* n. gen. from Chickamauga R. near Ringgold, Ga. and streams trib. to Tenn. R.

———1877—Contributions to N. American Ichthyology. II. A. Notes on Cottidae, Etheostomatidae, Percidae, Centrarchidae, Aphododeridae, Dorysomatidae, and Cyprinidae, with revisions of the genera and descriptions of new or little-known species. B. Synopsis of the Siluridae of the Fresh Waters of N. America. Bull. U. S. Natl. Mus. **10**:1-120. 45 pls.* *Pelodichthys olivaris,* French Broad R. (Pl. 34-35); *Noturus elutherus,* French Broad R. (Pl. 40); Tar. R. (Pl. 40-41).

———1977—A Partial Synopsis of the Fishes of upper Georgia, with supplementary papers on Fishes of Tennessee, Kentucky, and Indiana. Annals N. Y. Lyc. Nat. Hist. **11**:307-377.*

———1877—On the Distribution of Fresh-Water Fishes of the U. S. Annals N. Y. Acad. Sci. **1**:4.* Lists many species from French Broad, Powell, and Clinch Rivers, Tenn.

———1877-1878—Review of Rafinesque's Memoirs on N. American Fishes. Bull. U. S. Natl. Mus. **1**(9):1-53.

——— AND A. W. BRAYTON. 1878—On the Distribution of the Fishes of the Alleghany region of S. Carolina, Georgia, and Tennessee, with descriptions of the new or little-known species. Bull. U. S. Natl. Mus. **12**:1-96. 7-237.* Fishes of the Cumberland basin, 71. Tennessee basin, 56.

——— AND JOSEPH SWAIN. 1883—List of Fishes collected in the Clear Fork of the Cumberland, Whitley Co., Kentucky, with descriptions of three new species. Proc. U. S. Natl. Mus. **6**:249-251.* 23 species are listed, with *Bolesoma susanae*, *Poecilichthys sagitta*, and *Etheostoma cumberlandicum* as n. spp.

———1890—Report of Explorations made during the summer and autumn of 1888, in the Alleghany region of Virginia, N. Carolina, and Tennessee, and in western Indiana, with an account of the Fishes in each of the river basins of those regions. Bull. U. S. Fish Comm. **8**:97-173. 15 pls. 1888 (1890).*

——— AND B. W. EVERMANN. 1896—The Fishes of North and Middle America. Bull. U. S. Natl. Mus. **47**: 4 vols. 1-3313.* Contains many Tenn. references.

KING, WILLIS. 1937—Notes on the Distribution of native Speckled and Rainbow Trout in the streams at Great Smoky Mountains National Park. Jour. Tenn. Acad. Sci. **12**(4):351-361. Oct.*

KIRSCH, PHILLIP H. 1893—Notes on a collection of Fishes from the Southern Tributaries of the Cumberland River in Kentucky and Tennessee. Bull. U. S. Fish Comm. **11**:257-268. 1891 (1893).* Collections made at various points between Nashville and the Big South Fork of the Cumberland.

KUHNE, EUGENE R. 1939—The Reelfoot Lake Creel Census. Jour. Tenn. Acad. Sci. **14**(1): 46-53. Jan. Report Reelfoot Lake Biol. Sta. **3**. Tabulation of results from 714 records by resident and non-resident fishermen.

———1939—Preliminary Report on the Productivity of some Tennessee Waters. Jour. Tenn. Acad. Sci. **14**(1):54-60. Jan.* Report Reelfoot Lake Biol. Sta. **3**. Statistics on fisheries yield from Open Lake, Lauderdale Co., Reelfoot Lake, and Cove Lake, Tenn.

———1939—A guide to the Fishes of Tennessee and the Mid-South. Div. of Game and Fish. Nashville. 1-128.* With 82 figs., illus. 79 species of fishes found in the region.

LEACH, G. C. AND M. C. JAMES. 1938—Propagation and Distribution of Food Fishes: Fiscal Year 1937. U. S. Dept. Comm. Bur. of Fisheries. Washington. Adm. Report no. 33. 461-492. Contains Tenn. statistics. Also see earlier reports.

MYERS, G. S. 1913—The Status of the Darter, *Richiella brevispina* (Coker). Copeia **163**. Lists *Poecilichthys flabellaris (cumberlandicus)*, Cumberland Gap, Tenn.

NICHOLSON, H. 1880—The Jack of Tennessee. Chicago Field. **13**:83. 367.

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RAFINESQUE, C. S. 1819—Natural History of the Fishes of the Ohio River and its Tributary Streams. Western Rev. & Misc. Mag. **1**:305-313.

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with a sketch of the Life, the Ichthyologic work, and Ichthyologic Bibliography of Rafinesque). By R. E. Call. 1-175. Burrows Bros. Cleveland.

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———1939—Age and Growth of the Red-Eared Sunfish in Reelfoot Lake. Jour. Tenn. Acad. Sci. **14**(1):61-71. Jan.* Report Reelfoot Lake Biol. Sta. **3**. Contrib. no. 26. Study of *Eupomotis microlophus*. 6 in length reached in third summer, sexual maturity during the second summer of life.

SMITH, HUGH M. 1896—Statistics of the Fisheries of Tennessee in 1894. Report of the Comm. U. S. Fish Comm. Washington 528-530.

———1898—Statistics of the Fisheries of the Interior Waters of the U. S. Report U. S. Fish Comm. **22**:489-574. 1896 (1898). Cont. Tenn. references.

———1907—The Fishes of N. Carolina. N. C. Geol. and Econ Survey **2**:1-452.* Lists *Moxostoma aureolum*, *Hypohomus squamatus*, and *Etheostoma camurum*, from Tenn.

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———1897—Selection of site, and operations at Irwin. Report U. S. Fish Comm. 1897-1904.

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Part 9. Amphibia. Reptilia

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———1909—Notes on some Salamanders and Lizards of North Georgia. Science N.S. **30**:122-124.

———1910—Ophidian notes at Thompson's Mills, North Georgia. Science N.S. **31**:426-427.

BAILEY, J. R. 1936—*Microhyla carolinensis* in northeastern Tennessee. Copeia No. 2: 115. Kingsport and Bluff City, Sullivan Co.

———1937—Notes on the Plethodont Salamanders of the southeastern U. S. Occ. Papers, Mus. Zool. Univ. of Mich. **364**:1-10.*

BAKER, LOUISE C. 1937—Mating Habtis and Life History of *Amphiuma tridactylum* Cuvier, and effect of pituitary injections. Jour. Tenn. Acad. Sci. **12**(2):206-218. April. Collections and Exps. from the Reelfoot Lake Biol. Sta., Tenn.

BANTA, A. M. AND W. L. MCATEE. 1906—The Life History of the Cave Salamander, *Spelerpes maculicandus* Cope. Proc. U. S. Natl. Mus. **30**:67-83.

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———1925—Records of some Salamanders from N. Carolina and Pennsylvania. Copeia **139**:9-12.

———1926—Records of some Amphibians and Reptiles from Kentucky. Copeia **152**:118-120.

———1928—Notes on some Amphibians and Reptiles from the Southeastern States, with description of a new Salamander from N. Carolina. Jour. E. Mitchell Sci. Soc. **43**(3-4):153. July. New form: *Amblystoma mabeei*.

BLANCHARD, FRANK N. 1920—A Synopsis of the King Snakes: Genus *Lampropeltis* Fitzinger. Occ. Papers, Mus. Zool. Univ. of Mich. **87**:1-7. 1 table. June 24. *L. getulus niger* and *L. rhombomaculata*, from Tenn.

———1920—A black *Pituophis*. Copeia **81**:30-33. April 15. From Murphy, Tenn.

———1922—The Amphibians and Reptiles of Western Tennessee. Occ. Paper, Mus. Zool. Univ. of Mich. **117**:1-18.*

———1924—The forms of *Carphophis*. Papers Mich. Acad. Arts. Sci. & Letters. **4**:527-530.

———1933—The Snakes of the genus *Virginia*. Papers Mich. Acad. Arts. Sci. & Letters. No. 3. *V. valeriae elegans*, Maxey, Tenn.; *V. valeriae valeriae*, Tyree Springs, Tenn.

BRANDT, B. B. 1933—An extension of the range of *Hyla gratiosa* LeConte. Copeia: 39.

BRIMLEY, C. S. 1904—Box Tortoises of southeastern N. America. Jour. E. Mitchell Sci. Soc. **20**:27.*

———1910—Records of some Reptiles and Batrachians from the southeastern U. S. Proc. Biol. Soc. Washington. **23**:9-18.*

———1912—Notes on the Salamanders of the North Carolina mountains, with descriptions of two new species. Proc. Biol. Soc. Washington. **25**:135-140. 2 pls.* *Plethodon metcalfi*, n. sp. and *Spelerpes ruber*, var. n. *schencki*.

———1926—Revised Key and List of Amphibians and Reptiles of North Carolina. Jour. E. Mitchell Sci. Soc. **42**(1):2.* Lists *Ancides aeneus*, from Tenn.

———1928—Yellow-Cheeked *Desmognathus* from Macon Co., N. Carolina. Copeia **166**:21-23.

BURT, C. E. AND M. D. 1929—A Collection of Amphibia and Reptiles from the Mississippi Valley, with field observations. Amer. Mus. Nov. No. 381:1-14.*

BURT, C. E. 1931—A Study of the Teiid Lizards of the genus *Cnemidophorus* with special reference to their Phylogenetic Relationships. Bull. U. S. Natl. Mus. **154**. *C. sexlineatus sexlineatus*, Nashville, Perryville, Somerville, Chattanooga, Spring City, and Roane Co., Tenn. Illus. with 38 figs.

———1937—The Lizards of the Southeastern United States. Trans. Kan. Acad. Sci. **40**:349-366.* An annotated list of species with key. For Tenn.: *Anolis carolinensis* Voigt; Blount, Hamilton, Sevier Counties. *Sceloporus undulatus undulatus* Latreille; Blount, Benton, Claiborne, Davidson, Dyer, Hamilton, Humphreys, Maury, Fentress, Henry, Knox, Madison, Obion, Roane, Sevier, Shelby, Union, and Sumner Counties. *Cnemidophorus sexlineatus sexlineatus* (Linn.); Benton, Fayette, Hamilton, Sequatchie, Davidson, Decatur, and Henry Counties. *Leiolopisma unicolor* (Harlan); Dyer, Hamilton, Henry, Obion, and Shelby Counties. *Eumeces fasciatus* (Linn.); Hamilton, Hickman, Knox, Montgomery, Roane, Benton, Blount, Carroll, Cumberland, Dyer, Franklin, Henry, Houston, Madison, Obion, Rhea, Sevier, Shelby, White and Williamson Counties. *Ophisaurus ventralis* (Linn.); Bradley, Knox, and Roane Counties.

———1938—The Frogs and Toads of the Southeastern United States. Trans. Kan. Acad. Sci. **41**:331-360. 14 figs.* For Tenn.: *Bufo americanus americanus* Holbrook; Carter, Cumberland, Henderson, Humphries, Perry, Roane, Smith, Whitley, Davidson, Hamilton, Obion, Sevier, and Sumner Counties. *Bufo woodhousii fowleri* Hinckley; Cumberland, Dickson, Fayette, Fentress, Grainger, Hamilton, Jefferson, Lauderdale, Macon, Moore, Roane, Smith, Union, White, Benton, Dyer, Henry,

McMinn, Madison, Obion, Sevier, and Shelby Counties. *Acris gyrllus* (LeConte); Henderson, Hickman, Humphries, Jefferson, Knox, Perry, Warren, Hamilton, Henry, Green and Obio Counties. *Pseudacris nigrita triseriata* (Wied.); Putnam, Blount, Dyer, Obion, and Sevier Counties. *Hyla avivoca* Viosca; Davidson, Chester and Obio Counties. *Hyla cinerea cinerea* (Schneider); Lauderdale, Montgomery, and Obion Counties. *Hyla crucifer* Wied.; Coffee, Putnam, Blount, and Sevier Counties. *Hyla versicolor versicolor* LeConte; Campbell, Decatur, Fentress, Knox, Loudon, Macon, Marion, Perry, Sevier, Smith, Union, White, Blount, Dyer, Henry, McMinn, Obion, and Shelby Counties. *Rana catesbiana* Shaw; Cheatham, Decatur, Fayette, Fentress, Hamilton, Knox, Lauderdale, Monroe, Pickett, Putnam, Union, Dyer, Green, Henry, Obion, and Sevier Counties. *Rana clamitans* Latreille; Putnam, Union, Blount, Obion, Polk, Roane, and Sevier Counties. *Rana palustris* LeConte; Carter, Henry, and Roane Counties. *Rana pipiens* Schreber; Blount, Carroll, Clay, Fayette, Humphrey, Putnam, Sequatchie, Sevier, Dyer, Hamilton, Henry, Obion and Shelby Counties. *Microhyla carolinensis* (Holbrook); Hamilton, Henry, McMinn, Shelby and Sullivan Counties.

BYRD, E. E. 1939—Certain Aspects of the Anatomy of a Two-Headed Turtle. Jour. Tenn. Acad. Sci. **14**(1):102-109. 1 pl.

CAGLE, F. R. 1937—Egg-Laying Habits of the Slider Turtle, *(Pseudemys troostii)*, the Painted Turtle *(Chrysemys picta)*, and the Musk Turtle *(Sternotherus odoratus)*. Jour. Tenn. Acad. Sci. **12**(1):87-95.* Contrib. no. 4, Reelfoot Lake Biol. Sta.

———1937—Notes on *Natrix rhombifera* as observed at Reelfoot Lake. Jour. Tenn. Acad. Sci. **12**(2):179-185. 1 pl. 1 fig. April. Diamond-back water snake.

CAHN, ALVIN R. 1937—The Turtles of Illinois. Ill. Biol. Monogr. **16**(1-2):1-218.* Contains several Tenn. records.

———1939—The Barking Frog, *(Hyla gratiosa)* in Northern Alabama. Copeia no. 1: 52-53. March 9.

CARR, A. F., JR. 1938—A new subspecies of *Pseudemys floridana*, with notes on the *floridana* complex. Copeia no. 3. 105-109. *P. hierglyphica*, Cumberland R., Tenn. *P. concinna*, from E. Tenn. and N. Ala.

CARTER, H. A. 1934—Georgia Records of *Gastrophryne carolinense*. (Holbrook). Copeia: 138.

CHADWICK, C. S. 1928—Adaptive Peculiarities of Blood Circulation and Aeration in Lungless Salamanders with particular reference to *Desmognathus monticola*. Bound thesis. 1-50. 9 pls. Vanderbilt Univ. Library. Nashville. May 21. Material collected in central Tennessee.

COCHRAN, DORIS M. 1938—An Addition to the Lizard Fauna of Tennessee. Copeia No. 2. 90. *Anolis carolinensis* from Waynesboro, Wayne Co., and from Big Frog Mt., Polk Co. Reported as "apparently new to the state." Was previously reported from Tenn. by Jones and Ressler. Copeia. 1927.

COPE, E. D. 1881—*Plethodon aeneus* from Nickajack Cave. Amer. Nat. **15**:878. Description of type.

———1889—Batrachia of North America. Bull. U. S. Natl. Mus. **34**:1-525.* For Tenn. see tables pp. 27, 42, 56, 135, 137, 143, 157, 170, 182, 197, 287, 331, 341, 376, 409, 427.

DITMARS, R. L. 1930—The Poisonous Serpents of the New World. Bull. N. Y. Zool. Soc. **33**:3. *Crotalus horridus* of Tenn.

DONNELL, T. A. 1936—The Development of the mesonephros and Müllerian Duct of the Turtle. Bound thesis. 1-31. Vanderbilt Univ. Library. Nashville. 7 pls. June. *Chelydra serpentina* from Nashville, Tenn.

DUNN, EMMETT R. 1917—The Pine Snake in Virginia. Copeia no. 51. 101. Nov. 26. Mentions specimen from Blount Co., Tenn.

———1917—Salamanders of the genera *Desmongnathus* and *Leurognathus*. Pub. no. 2211. Proc. U. S. Natl. Mus. **53**:393-433.* With maps and description of range for these forms in N. Carolina and Tenn.

———1917—Reptile and Amphibian collections from the N. Carolina mountains, with special reference to Salamanders. Bull. Amer. Mus. Nat. Hist. **37**:593-634.*

———1918—The collection of Amphibia Caudata of the Museum of Comparative Zoology. Bull Mus. Comp. Zool. Harvard Coll. **62**(9):445-471. Dec. Lists species from Tennessee.

———1920—Some Reptiles and Amphibia from Virginia, Carolina, Tennessee and Alabama. Proc. Biol. Soc. Washington **33**:129-138. Dec. 30. Inc. *Coluber constrictor constrictor* from Spring City, Tenn.

———1926—The Salamanders of the family Plethodontidae. Smith Coll., Northampton, Mass. 1-441. With many pls. and maps.* An important reference for this group in Tenn. and adjacent areas.

———1927—*Hyla phaeocrypta* in Tennessee. Copeia No. 162. 19. March. From Nashville, Tenn.

———1927—A new mountain race of *Desmognathus*. Copeia No. 164. 84-86.

———1927—On the relationship of certain Plethodont Salamanders. Copeia no. 165. 102-106.

ENDSLEY, J. R. 1937—The occurrence of *Hyla avivoca* in Western Tennessee. Copeia **1**:70. Henderson, Chester Co.

FOWLER, H. W. AND E. R. DUNN. 1917—Notes on Salamanders. Proc. Acad. Nat. Sci. Philad. **69**:7-28. 2 pls.* Studies of N. Carolina and Tenn. species.

GENTRY, GLENN. 1937—A Preliminary Survey of the Amphibia of Tennessee. Bound thesis. 1-107. Peabody Coll. Library. Nashville. August.* With maps and tables, showing distribution of species in Tenn. by counties.

GLOYD, H. K. AND R. CONANT. 1938—The subspecies of the Copperhead, *(Agkistrodon mokasen* Beauvois). Bull. Chicago Acad. Sci. **5**(7):163-166. *A. mokasen mokasen*, So. Ill. and E. Central Ala. *A. mokasen cuperus*, Tenn. R. and N. E. Ala.

HARPER, FRANCIS. 1935—Records of Amphibians for the Southeastern States. Amer. Midl. Nat. **16**:275-310.* *Bufo fowleri*, Etowah, Tenn.; *Hyla crucifer*, Gatlinburg, Tenn.; *Hyla versicolor versicolor*, Etowah; *Rana clamitans*, Parksville and Gatlinburg; *Gastrophryne carolinensis*, Etowah.

HASSLER, W. G. 1929—Salamanders of the Great Smokies. Nat. Hist. (N. Y.) **29**(1):95-100.*

HIBBARD, C. W. 1937—The Amphibia and Reptiles of Mammoth Cave National Park (Proposed). Trans. Kan. Acad. Sci. **39**:277-281.

HOLT, E. G. 1924—Additional Records for the Alabama herpetological catalogue. Copeia 135:93-95; 136:100-101.

JONES, J. P. AND B. C. V. RESSLER. 1927—The occurrence of *Anolis carolinensis* Voigt in eastern Tennessee. Copeia 164. 87-88.

———1928—A few facts regarding some Tennessee Snakes. Jour. Tenn. Acad. Sci. **3**(2):14-24. 1 fig. April.* Popular acct., with a list of 6 lizards, 30 snakes, and 11 turtles.

KLINE, E. K. AND N. M. FULLER. 1932—Interpretation of Laboratory finds in Rural Spring Water Supplies. Amer. Jour. Pub. Health **22**(7):691-699. Lists *Gryinophilus porphyriticus* and *Desmognathus fuscus* from Tenn. Paper deals with *B. coli* in spring water and salamanders as hosts thereof.

KING, WILLIS. 1936—A new Salamander *(Desmognathus)* from the Southern Appalachians. Herpetologica **1**(2):58-60. *D. wrighti*, Mt. LeConte, Sevier Co., Tenn.

———1939—A Survey of the Herpetology of Great Smoky Mountains National Park. Amer. Midl. Nat. **21**(3):531-582.*

KLAUBER, L. M. 1936—A Key to the Rattlesnakes with a summary of Characteristics. Trans. San Diego Soc. Nat. Hist. (Calif.) **8**:20.* *Sistrurus miliarius streckeri; Crotalus horridus horridus; C. horridus atricaudatus*, species found in Tennessee.

LODING, H. P. 1922—A Preliminary Catalogue of Alabama Amphibians and Reptiles. Geol. Survey of Ala. Papers Ala. Mus. Nat. Hist. **5**:1-53. Sept.*

MCCLURE, GERVASE W. 1931—The Great Smoky Mountains, with preliminary notes on the Salamanders of Mt. LeConte and LeConte Creek. Zoologica N. Y. **11**(6): 53-76. 2 maps. 7 pls.* Study of *Desmognathus quadra-maculatus; D. phoca; D. fuscus carolinensis; Plethodon jordani; Gyrinophilus danielsi; Eurycea bislineata wilderae.* An ecological investigation.

MOORE, J. P. 1899—*Leurognathus marmorata*, a new genus and species of Salamander of the family Desmognathidae. Proc. Acad. Nat. Sci. Philad. **51**:316-323. From Grandfather Mts., N. C. Alt. 3500 ft.

NECKER, W. L. 1934—Contribution to the Herpetology of the Smoky Mountains of Tennessee. Bull. Chicago Acad. Sci. **5**:1-4. 7 anurans, 2 lizards, 10 snakes, 2 turtles, are described from the region.

NOBLE, G. K. 1927—The Plethodontid Salamanders; some aspects of their Evolution. Amer. Mus. Nov. **249**:1-26. 10 figs.*

ORTENBURGER, A. I. 1928—The Whip Snakes and Racers. Univ. of Mich. Publ. Ann Arbor. 1-247.* *Coluber constrictor;* from Tenn.

PARKER, M. V. 1937—Some Amphibians and Reptiles from Reelfoot Lake. Jour. Tenn. Acad. Sci. **12**(1):60-86. Jan.* An annotated listing of specimens collected during 1935-1936. Contrib. no. 3, Reelfoot Lake Biol. Sta.

———1939—The Amphibians and Reptiles of Reelfoot Lake and Vicinity, with a Key for the separation of species and subspecies. Jour. Tenn. Acad. Sci. **14**(1): 72-101.* Records of collections with an account of relative abundance. Illustrated.

POPE, C. H. 1928—Some Plethodontid Salamanders from North Carolina and Kentucky, with description of a new race of *Leurognathus*. Amer. Mus. Nov. **306**:1-19. April 14. Records *D. fuscus carolinensis*, Gatlinburg, Tenn.

RHOADES, S. N. 1895—Contributions to the Zoology of Tennessee. No. 1. Reptiles and and Batrachians. Proc. Acad. Nat. Sci. Philad. **47**:376-407.

RUTHVEN, A. G. 1908—Variations and genetic relationships of the Garter Snakes. Bull. U. S. Natl. Mus. **61**:1-198.* Inc. *Thamnophis sauritis* and *T. sirtalis*, from Tenn.

SIEBENROCK, F. 1907—Die Schildkrötenfamilie Cinosternidae. Sitzber. d. Wiener Akad. 1 Abt. **116**:527-599. Mentions Tennessee turtle records: *Sternotherus minor*, and *S. odoratus*.

SMITH, HOBART M. 1938—A Review of the Snake genus *Farancia*. Copeia no. 3: 110-117. Records *F. abacura reinwardtii* on map of West Tennessee, vicinity of Gilbertsville Reservoir, T. V. A.

———1938—Remarks on the status of the subspecies of *Scelophorus undulatus*, with descriptions of new species and subspecies of the *undulatus* group.* Occ. Papers, Mus. Zool. Univ. of Mich. **387**:1-17. Oct. 31. *S. undulatus fasciatus* from Bluff City, Sullivan Co., Sugar Loaf Mt., and Jackson, Madison Co., Tenn.

STEJNEGER, LEONHARD. 1906—A new Salamander from North Carolina. Pub. no. 1457. Proc. U. S. Natl. Mus. **30**:559-562. *Plethodon shermani.*

———1923—Rehabilitation of a hitherto overlooked species of Musk Turtle of the Southern States. Proc. U. S. Natl. Mus. **62**:1-3. *Sternotherus minor*, Roane Co., Tenn. Previously called *S. carinatus* by Rhoades, 1895.

TAYLOR EDWARD H. 1935—A Taxonomic Study of the cosmopolitan Scincoid Lizards of the genus *Eumeces*. Bull. Univ. Kansas Sci. Bull. no. 23: 643.* Lists *E. fasciatus; E. laticeps*, from Tenn. *E. anthracinus*, from N. W. corner of N. C.

TRAPIDO HAROLD. 1938—*Lampropeltis getulus nigra* (Yarrow) in West Virginia and Western Tennessee. Copeia no. 1: 49.

UNTERSTEIN, W. 1929—Bemerkungen zur Fortpflanzung von *Desmognathus fuscus* Raf. Sitzber. d. Ges. Naturfor. zu Berlin. 243-249. Locality: N. Carolina.

VIOSCA, PERCY. 1937—A tentative revision of the genus *Necturus*, with descriptions of three new species from the Southern Gulf Drainage area. Copeia no. 2:120-139.* Lists and maps range of *N. maculata* from Tenn. and N. Ala.

WALKER, C. F. 1931—Description of a new Salamander from North Carolina. Proc. Junior Soc. Nat. Hist. Cincinnati Memoir no. 3-5. *Plethodon welleri*, Grandfather Mts.

WELLER, W. H. 1930—Notes on *Aneides aeneus* Cope and Packard. Proc. Junior Soc. Nat. Hist. Cincinnati. **1**(1):2-3. First records for Gt. Smoky Mts., Tenn.

———1930—A new Salamander from the Great Smoky Mountains National Park. Proc. Junior Soc. Nat. Hist. Cincinnati. **1**:7. *Desmognathus aureatagulus*, n. sp. from near Newfound Gap, Tenn.-N.C. line.

———1931—A Preliminary List of the Salamanders of the Great Smoky Mountains of N. Carolina and Tennessee. Proc. Junior Soc. Nat. Hist. Cincinnati. **2**(1): 21-32.* An annotated list of 12 species with descriptive and taxonomic notes and habitat records.

WILDER, I. W. 1913—The Life-History of *Desmognathus fusca*. Biol. Bull. **24**(4-5): 251-343.*

WRIGHT, A. H. AND A. A. 1924—Key to the Eggs of the Salienta East of the Mississippi River. Amer. Nat. **58**:375-381. 1 pl. Refers to species common to Tenn.

———1929—Synopsis and Descriptions of North American Tadpoles. Proc. U. S. Natl. Mus. **74**:1-70. 9 pls.* Species from Eastern and Southern U. S.

WRIGHT, A. A. AND A. H. 1933—Handbook of Toads and Frogs: The Toads and Frogs of the U. S. and Canada. Comstock. Ithaca, N. Y. 1-231. 89 figs.*

YARROW, H. C. 1882—Check-List of North American Reptilia and Batrachia. Bull. U. S. Natl. Mus. no. 24: 1-249.* For. index of Tennessee localities, see p. 215.

Part 10. Aves

(This section contains references to local lists of general ornithological interest.)

A(LLEN), J. A. 1896—Rhoad's List of Tennessee Birds. Auk **13**:244-245. A critical review.

ALLISON, ANDREW. 1907—Notes on the spring Birds of Tishomingo County, Mississippi. (With general notes on the fauna and flora). Auk **24**:12-25. Records some Tennessee species.

ANDERSON, J. 1928—Notes on the Birds about Memphis. Bird Lore. **30**:294. Western Tenn.

BAILEY, VERNON. 1905—Birds known to eat the Boll Weevil. Bull. Biol. Survey U. S. D. A. (22):1-16. Western meadow lark, Killdeer, Brewer's blackbird, lead in weevils devoured.

BAIRD, CHARLES. 1937—A Least Bittern near Knoxville. The Migrant **8**(4):87. Dec. From Andrew Jackson Lake, East Tennessee.

BAMBERG, J. 1937—Notes from Wheeler Dam. The Migrant **8**(2):40.

BARTRAM, J. 1791—Travels through N. and S. Carolina, Georgia, East and West Florida. Philad. (Copy in Lib. of Tenn. Historicaal Soc.*)

BARTSCH, PAUL. 1922—Some Tern Notes. Auk **39**:101. Jan. Least and Black Terns in Tennessee.

BELLROSE, FRANK. 1938—Notes on Birds of the Great Smoky Mountains National Park. The Migrant **9**(1):1-4. March.* An annotated list of 59 species.

BENT, A. C. 1919—North American Diving Birds. Bull. U. S. Natl. Mus. **107**. Contains Tenn. data.

———1921—Life Histories of North American Gulls and Terns. Bull. U. S. Natl. Mus. **113**. Contains Tenn. data.

———1925—Life Histories of North American Wild Fowl. Bull. U. S. Natl. Mus. **130**. Cont. note on breeding of Canada geese at Reelfoot Lake. 222.

———1926-1927—Life Histories of N. American Marsh Birds. Bull. U. S. Natl. Mus. I. **135**. (Note on breeding of American Egret, p. 145. Coot, p. 367.) II. **142**. (Record for Eastern Dowitcher, Reelfoot Lake, p. 115).

BIRDS OF THE NATIONAL PARKS: CHECK-LIST OF. 1937—Natl. Park Service. Washington (Mimeographed). Dec.* Contains a list of Birds from the Gt. Smoky Mts. Natl. Park, Tenn.

BIRDS OF TENNESSEE: PRELIMINARY LIST OF. 1917-1933—Compiled by the Tenn. Ornith. Soc. 1917, 1st. ed. 1933 2nd ed. Div. of Game and Fish, State of Tenn. Nashville.

BRASFIELD, S. A. 1932—The Nesting Habits of the Wood Thrush. (in Tenn.) Bound thesis. 1-89. Peabody Coll. Library. Nashville. August.*

BREWSTER, WILLIAM. 1886—An Ornithological Reconnaissance in Western North Carolina. Auk **3**:94-112. 173-179.

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SUMNER CO., TENN.—Burt, 1937, 1938.
SWAIN CO., N. C.—Clench & Banks, 1932.

TATE, GA.—Howell, 1909.
TAZEWELL, TENN.—Hughes, 1910-14; Faxon, 1898.
TENNESSEE RIVER.—Agassiz, 1854; Fowler, 1922; Gilbert, 1887-1889; Jordan & Brayton, 1877; Conrad, 1834; Goodrich, 1921, 1931, 1934, 1935-37, 1938; Lea, 1830, 1841, 1857, 1861, 1868-72; Ortmann, 1920, 1923-24, 1925; Remington & Clench, 1925; Simpson, 1900; Sterki, 1905; Troost, 1844; Tryon, 1866; Walker, 1916; Wetherby, 1881; Johnson, 1905.
THREE SPRINGS CAVE, (TENN.)—Ives, 1935, 1938.
TIPTONVILLE, TENN.—Ganier, 1929, 1930; Mattox, 1936.
TISHOMINGO CO., MISS.—Allison, 1907.
TUCKASEEGEE RIVER, (N. C.)—Hildebrand, 1932.
TULLAHOMA, TENN.—DeLong & Mohr, 1936.
TUSCUMBIA, ALA. (See Muscle Shoals)—Lea, 1865.
TYREE SPRINGS, TENN.—Allen, 1864, 1893; Blanchard, 1933.

UNICOI CO., TENN.—Baker, 1929, 1930.
UNION CO., TENN.—Pilsbry, 1924; Wing, 1938; Burt, 1937, 1938.

VALLEY RIVER MTS. (N. C.)—Clench & Banks, 1932.

WALDEN'S RIDGE (TENN.)—Howell, 1910.
WARREN CO., TENN.—Goodrich, 1923; Burt, 1938.
WATAUGA CO., N. C.—Clapp, 1920.
WAYNESBORO, TENN.—Cochran, 1938.
WEBSTER CO., MISS.—Yeager, 1937.
WETUMPKA, ALA.—Clapp, 1904.
WHEELER DAM (TENN.)—Bamberg, 1937; Cahn & Bryan, 1938.
WHITE BLUFF, TENN.—Shaver, 1936.
WHITE CO., TENN.—Goodrich, 1923; Burt, 1937, 1938.
WILLIAMSON CO., TENN.—Burt, 1937.
YOUNG HARRIS, GA.—Howell, 1909.

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Spirocerca longispiculata n. sp.*

William C. Hill

In an examination of 19 opossums, *Didelphis virginiana virginiana* Kerr, collected at various times in 1938 in central Oklahoma, 2 were found to harbor 7 and 26 specimens, respectively, of a new spiruroid stomach nema belonging apparently to the genus *Spirocerca* Railliet and Henry 1911, for which the name *Spirocerca longispiculata* is proposed.

The worms were all fixed in hot 70 percent alcohol, cleared in a mixture of glycerolactophenol (Magath 1916), and later transferred to glycerin for storage.

In order to study the arrangement of papillae and cuticular crests on the ventral surface of the male tail, the tail was cut off, just anterior to the alae, and straightened under heavy cover glass pressure. Ventral views of the female tail were prepared in much the same manner. For *en face* study a small square-cut section was taken from the front end of the worm and mounted upright in glycerin.

The terms, *pseudolabium, interlabium,* names of cephalic papillae, *amphid, deirid, phasmid, stoma, prostom, mesostom, telostom, prorhabdion, mesorhabdion,* and *telorhabdion,* are used as by Chitwood and Wehr (1934).

Spirocerca longispiculata sp. nov.

Description.—Body reddish-brown, translucent. Cuticle rather thick, with very fine transverse striations. Pseudolabia and interlabia present but not prominent. Pseudolabia reniform with tips directed forward. Amphids and external cephalic papillae on pseudolabia. Laterodorsal and lateroventral papillae prominent. Dorsodorsal and ventroventral papillae rudimentary but recognizable. Internal papillae, 3 pairs, small but well defined. Dorsodorsal, laterodorsal, and internodorsal papillae on either side connected to a single, large cephalic "pulp." Ventral papillae likewise associated with a single pair of pulps.

Stoma heavily chitinized. No "teeth" observed. Prorhabdion, with anterior and posterior internal annular flanges. Mesorhabdion narrower than prorhabdion and about 4 times as long, uniformly cylindrical. Telorhabdion, an outspreading flange. Boundary between short anterior muscular and much longer glandular parts of esophagus, distinct. Nerve ring near middle of muscular part of esophagus. Excretory pore slightly posterior to nerve ring. Excretory duct leads posteriad to an elongate, saccate, enlargement. Right deirid slightly posterior to nerve ring, left deirid near level of, or slightly behind, telostom.

* A contribution from the Zoological Laboratory of the Oklahoma Agricultural and Mechanical College, prepared under the direction of R. Chester Hughes.

Female.—Darker in color and considerably larger than male. Body curved dorsad. Measurements taken from 6 gravid, preserved specimens. Length 5.8 to 7.6 (average 6.9) mm. Width near middle of body 185 to 227 (average 198) μ. Length of stoma 72 to 87 (average 80) μ, width near middle, 19 to 21 (average 20) μ. From anterior end—right deirid 206 to 221 (average 215) μ, left deirid 82 to 121 (average 100) μ, nerve ring 167 to 191 (average 176) μ, excretory pore 213 to 238 (average 225) μ. Length of esophagus 1.4 to 1.5 (average 1.47) mm., length of muscular portion 190 to 216 (average 209) μ, width at base of muscular part 37 to 50 (average 44) μ, width at base of glandular part 85 to 114 (average 94) μ.

Vulva generally slightly protuberant, near middle of body, 2 to 3.36 (average 2.76) mm. from anterior end. Vagina short. Uteri divergent. Anterior ovary located just posterior to esophagus, posterior ovary slightly anterior to anus. Uteri, 71 to 142 (average 110) μ in width, filled with eggs. Embryonated eggs in distal part of uterus 18 to 31.5 (average 24) μ long by 10 to 15 (average 13) μ wide.

Tail short, curved dorsally, ends in a prominent variously shaped protuberance bearing from 1 to 4 smaller points or knobs. Phasmids large, ventrosubmedian, located about midway between anus and tip of tail.

Male.—Lighter in color and smaller than female. Posterior tip, in preserved specimens, curved ventrally in from 1 to 2 loose spiral coils. Measurements from 5 of the largest males. Lenth 4.2 to 5.36 (average 5.33) mm. Width near middle of body 121 to 149 (average 136) μ. Stoma 71 to 82 (average 79) μ long, width near middle 14.2 to 17.7 (average 16.6) μ. From anterior end—right deirid 192 to 245 (average 219) μ, left deirid 85 to 123 (average 94) μ, excretory pore 211 to 238 (average 222) μ, nerve ring 170 to 195 (average 175) μ. Esophagus length 1.4 to 2 (average 1.7) mm., length of muscular part 177 to 239 (average 208) μ, width at base of muscular part 37 to 44 (average 40.4) μ, width at base of glandular part 78 to 106 (average 88) μ.

Spicules very unequal in length and width—in a 5-mm. worm the right spicule measured 140μ in length and 90μ in width at base, the left 380μ by 60μ.

Ventral surface of coiled region (approximately the posterior fifth of body) covered with a pattern of cuticular crests and bosses which spreads out to cover the surfaces of the small alae. Tail provided with 4 pairs of preanal, and 2 pairs of postanal, large pedunculated papillae supporting the alae, a very large median sessile precloacal papilla, and a group of five pairs of minute pedunculated papillae on posterior tip. Small paired marginal areas on dorsal surfaces of alae covered with fine transverse, almost parallel, wrinkles. These areas widest posteriorly. Subsurfical areas surrounding tips of the first 5 pairs of large pedunculated papillae filled with irregular granules.

Host.—*Didelphis virginiana virginiana* Kerr.

Habitat.—Stomach.

Locality.—Central Oklahoma.

Cotype specimens.—A vial of several alcoholic specimens in the United States National Museum.

Discussion

According to Yorke and Maplestone (1926) the genus *Spirocerca* Railliet and Henry 1911 belongs to the family Spiruridae Oerley 1885 and the subfamily Spirurinae Railliet 1915. Chitwood and Wehr (1934) place the genus in the family Thelaziidae Railliet 1916 and the subfamily Spirocercinae Chitwood and Wehr 1932.

The genus now includes 4 species—(1) The type *Spirocerca lupi* (Rudolphi 1809) Chitwood 1933 [=*Spirocerca sanguinolenta* (Rudolphi 1819) Seurat 1913] parasitic in Canidae and reported from both hemispheres; (2) *Spirocerca arctica* Petrow 1927 in Canidae in northern Russia; (3) *Spirocerca heydoni* Baylis 1927 from *Dasyurus* sp. in Australia; and (4) *Spirocerca longispiculata* n. sp. Two other species formerly listed in the genus as *Spirocerca subaequalis* (Molin 1860) Seurat and *Spirocerca felineus* Chandler 1925, are now *Cylicospirura subaequalis* (Molin) Vevers and *Cylicospirura felineus* (Chandler) Sandground.

The new species is seemingly not closely related to any of the other species in the genus, differing apparently from all of them in having, (1) definite pseudolabia, (2) recognizable dorsodorsal and ventroventral external cephalic papillae, (3) an exceptionally long mesostom, (4) the cervical papillae in markedly asymmetrical arrangement, (5) no accessory piece observed, (6) paired caudal papillae of male all pedunculated, (7) dorsal transverse wrinkles on caudal alae of male, (8) a prominent posteroterminal protuberance on

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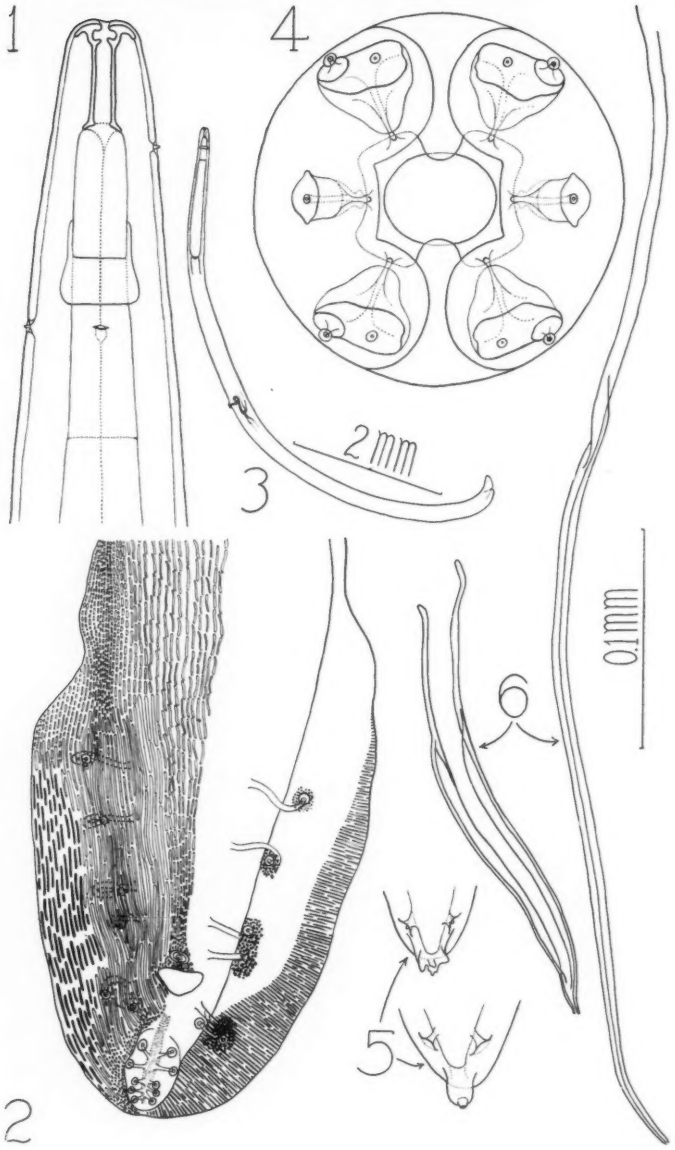
EXPLANATION OF PLATE

All figures concern *Spirocerca longispiculata* n. sp. and except Fig. 4 were drawn with the aid of a camera lucida. The scale at the right applies to figures 1, 2, 5, and 6.

FIGURES

1. Anterior end of body, ventral view—shows stoma, nerve ring, deirids, excretory pore, and boundary between muscular and glandular sections of esophagus.
2. Posterior end of male, ventral view. Superficial cuticular pattern of alternating depressed and elevated areas shown on left side. Over most of this surface the elevated areas are discontinuous as longitudinal ridges but in the marginal regions adjacent to the large pedunculated papillae the depressed areas become discontinuous as longitudinal grooves represented in heavy shading. On the right side are shown the subsurficial granules surrounding the tips of the 5 foremost lateral papillae and the dorsal area of transverse wrinkles.
3. Female, lateral view—shows dorsad curvature of body and relative positions of stoma, esophagus (muscular and glandular portions), vulva, and anus.
4. *En face* view—shows psedolabia, interlabia, arrangement of cephalic papillae, and amphids.
5. Female tail, 2 specimens in ventral view—shows phasmids and variation in shape of posterior protuberance.
6. Pair of spicules, not in natural relationship to one another. The longer spicule is the left one.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the female, (9) not been found in cysts or tumors, and (10) a smaller size. Furthermore *S. longispiculata* differs from *S. lupi*, the only other species reported from North America, in having (1) divergent uteri, (2) the vulva near the middle of the body instead of near the esophagus, and (3) a much longer and narrower stoma; from *S. arctica* in having (1) a different arrangement of caudal papillae in the male with no postanal sessile papilla and (2) no teeth in the stoma; and from *S. heydoni*, the only other species found in a marsupial, in having (1) the vulva much farther posteriad and (2) no teeth in the stoma.

The new form has been placed in the genus *Spirocerae* because it agrees with the type species in having (1) the internal papillae ("dents"—Railliet and Henry 1911) within the stoma, (2) 6 prominent cephalic papillary pulps ("masses of dense parenchyma"—Yorke and Maplestone 1926), (3) the same number and general arrangement of male caudal papillae, including the especially prominent precloacal median sessile papilla, and (4) very unequal spicules, the left being the longer.

If the placement of the new species in the genus *Spirocerca* should meet with the general approval of subsequent workers an emendation of the generic description will be necessary since it differs from the very brief definition of Baylis (1929) in the exceptional length of the vestibule and from the diagnosis of Yorke and Maplestone (1926) in having (1) pseudolabia, (2) recognizable dorsodorsal and ventroventral cephalic papillae, (3) the deirids in markedly asymmetrical arrangement, (4) the vulva farther posteriad, (5) divergent uteri, and (6) no gubernaculum observed.

Key to the Species of Spirocerca

1. Prostomatal teeth present 2
   Prostomatal teeth lacking 3
2. Prostomatal teeth "tricuspid" ..... *S. heydoni*
   Prostomatal teeth simple ..... *S. arctica*
3. Deirids nearly or quite opposed ..... *S. lupi*
   Deirids asymmetrically placed ..... *S. longispiculata*

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Hymenolepis scalopi n. sp.*

Richard L. Schultz

An apparently new hymenolepidid tapeworm was found in moles, *Scalopus aquaticus intermedius* (Elliot)**, in the vicinity of Stillwater, Oklahoma, in 1938. Two out of eight specimens collected in the spring and one of five taken in the fall harbored three, six, and two of the worms respectively. The name *Hymenolepis scalopi* is proposed for this form.

The worms were studied both alive and preserved. They were fixed either in Gilson's or Bouin's fluid, stained in borax carmine, cleared in toluol, and mounted in balsam. Some of the pieces were later removed from the balsam, sectioned, and stained in Ehrlich's acid haematoxylin. All of the measurements recorded below, except the length and width of the entire strobila, were taken from preserved specimens.

Hymenolepis scalopi sp. nov.

Description.—Live strobila, straightened out but not stretched, 10-20 cm. long and 3 mm. in maximum width. Two longest specimens with 999 and 1070 proglottides respectively. Margins serrate. Scolex unarmed, 170-232 μ in diameter. Suckers aspinous, 80-110 μ in diameter. Rostellum 78-117 μ long by 48-62 μ in diameter. Neck 0.8-1.5 mm. long and 130-150 μ wide. Fully mature proglottides with sperm-distended seminal receptacles first appear at from 500 to 550 segments from the neck. Widest segments 15 to 20 times as wide as long.

Ovary 125-220 μ wide in mature proglottides, centrally or subcentrally located, not at all bilobate, roughly reniform in dorsal view with concavity directed posteriad and with anterior convex side subdivided into from 5 to 7 coarse lobes. Vitellarium 50-80 μ wide, compact, immediately posteroventrad to central part of ovary. Mehlis's gland and ootype located dorsal to and between ovary and vitellarium and slightly toward poral side of proglottis.

Uterus in young segments, a small sac extending anterodorsoaporad from ootype. Later it becomes a narrow transverse tube traversing almost entire width of proglottis and covered on all sides with numerous outpouchings. Fully gravid it almost fills length of segment, outpocketings being no longer evident. Vagina opens into atrium directly ventrad to cirrus. Seminal receptacle large, comprises greater part of length of vagina, variously marked by constrictions, and filled with sperms in fully mature segments.

* Contribution from the Zoological Laboratory, Oklahoma Agricultural and Mechanical College, prepared under the direction of R. Chester Hughes.

** Moles taken in the vicinity of Stillwater were identified as *Scalopus aquaticus intermedius* by Mr. W. Frank Blair of the Museum of Zoology, University of Michigan.

Outer egg membrane 57-65 μ in diameter, inner shell with opposed thickenings but without filaments. Oncosphere 27-30 μ in diameter. Hooks (Fig. 4) of embryo, with distinct shafts and curved claws, 16-18 μ long.

Testes, usually one poral and two aporal, somewhat spheroidal (80-90 μ in diameter) in younger segments, more or less ellipsoidal (115-153 μ by 77-99μ) in fully mature ones. Poral and one aporal testis generally located along posterior margin of proglottis on either side of ovary and dorsal to transverse excretory canal. One aporal testis usually anterolaterad, but frequently anteromesad or even directly anteriad, to the other. Other variations in arrangement of testes: (1) all in a straight line, (2) two poral and one aporal, (3) all poral, (4) all aporal (Fig. 6). Occasionally four, less frequently only two, testes occur.

Cirrus pouch, 125 by 45 μ in mature, and 132 by 47 μ in gravid, segments; rarely extends mesad farther than two-thirds distance from margin to poral ventral excretory canal. Cirrus unarmed, seen slightly protruded from genital atrium in some specimens. Internal and external seminal vesicles both prominent. Vas deferens in passing from internal to external vesicle effects a single reverse dorsoposteriad spiral turn with a central dilatation. External vesicle often lies partly, sometimes wholly, lateral to excretory canals. Aporal vasa efferentia unite aporad to ovary, thence with poral vas efferens dorsal to ovary. Vas deferens very narrow for greater part of its length.

Ventral excretory canals much larger than dorsal canals. Ventral canals connected in posterior part of each proglottis by a prominent transverse commissure. No transverse commissures between dorsal canals observed in proglottides. On either side ventral canal continuous with dorsal canal near base of rostellum (Fig. 8). Dorsal canals connected by a transverse tube (the only dorsal cross connection observed in the entire worm) shortly behind rostellum. A pair of small collecting tubules extends from regions of continuity between dorsal and ventral canals on either side into rostellum.

Bundles of deep longitudinal muscle fibers in two concentric layers—about 140 bundles in outer layer and from 30 to 40 in inner layer (Fig. 5).

Host.—*Scalopus aquaticus intermedius* (Elliot 1899).

Haibtat.—Lumen of small intestine.

Locality.—Stillwater, Oklahoma.

Type material.—One complete strobila mounted *in toto* in balsam on a series of eight microscope slides, in United States National Museum.

Discussion

According to Hughes (unpublished ms.) the genus *Hymenolepis* Weinland 1858 contains over 300 species parasitic in birds and mammals. Of the 63 mammalian species, 30 occur in insectivores, 21 in rodents, 8 in bats, 4 in primates, and 1 in a marsupial. Twenty-one of the insectivoran forms have armed scoleces. In two others, *H. barroisii* (Moniez 1880) Fuhrmann 1924

and *H. capensis* von Janicki 1904, both insufficiently described Old World species, the scolex is unknown. The unarmed insectivoran species include *H. alpestris* Baer 1931, *H. anthocephalus* Van Gundy 1935, *H. diaphana* Kholodkowski 1906, *H. erinacei* (Gmelin 1790) Blanchard 1891, *H. globosa* Baer 1931, *H. peipingensis* Hsü 1935, and *H. soricis* Baer 1925.

Of the unarmed insectivoran species the new form is most like *H. erinacei* and *H. peipingensis*. It differs from the former (as described by Joyeux and Baer 1936) in that (1) it is wider, (2) the scolex, rostellum, and suckers are much smaller, (3) the testes are not normally in a straight line, (4) the cirrus does not extend to the poral ventral excretory canal, (5) the eggs are appreciably larger, and (6) it has a mole rather than a hedgehog host. *H. scalopi* differs from *H. peipingensis* (as described by Hsü 1935) in that (1) it is much shorter and somewhat wider, (2) the cirrus pouch does not extend to the poral ventral excretory canal, (3) the testes are much larger, and (4) both mature and gravid proglottides are considerably wider in proportion to length.

Among the noninsectivoran mammalian unarmed species the new form most resembles *H. diminuta* (Rudolphi 1819) Blanchard 1891. In comparing my specimens with *H. diminuta* both descriptions (Ransom 1904, Meggitt and Subramanian 1927, Baylis 1929, and Joyeux and Baer 1936) and specimens (from local rats and mice) of the latter were studied. *H. scalopi* differs from *H. diminuta* in that (1) the cirrus pouch is shorter and does not reach the ventral excretory canal, (2) the vasa efferentia are not convergent at a common point, (3) the ovary is much more coarsely lobed and not bipartite, (4) the testes are relatively smaller and usually not in a straight line, (5) the strobila, on the average, is shorter and relatively wider, (6) the scolex is actually smaller with suckers and rostellum relatively larger, and (7) the margins of the strobila are more serrate.

Apparently only two species of *Hymenolepis* have heretofore been reported from insectivores in North America, namely, (1) *H. bacillaris* (Goeze 1782) Blanchard 1891 reported from *"Scalops aquaticus"* by Leidy in 1904 according to Meggitt (1924) and (2) *H. anthocephalus* described by Van Gundy (1935) from *Blarina brevicauda* in Michigan.

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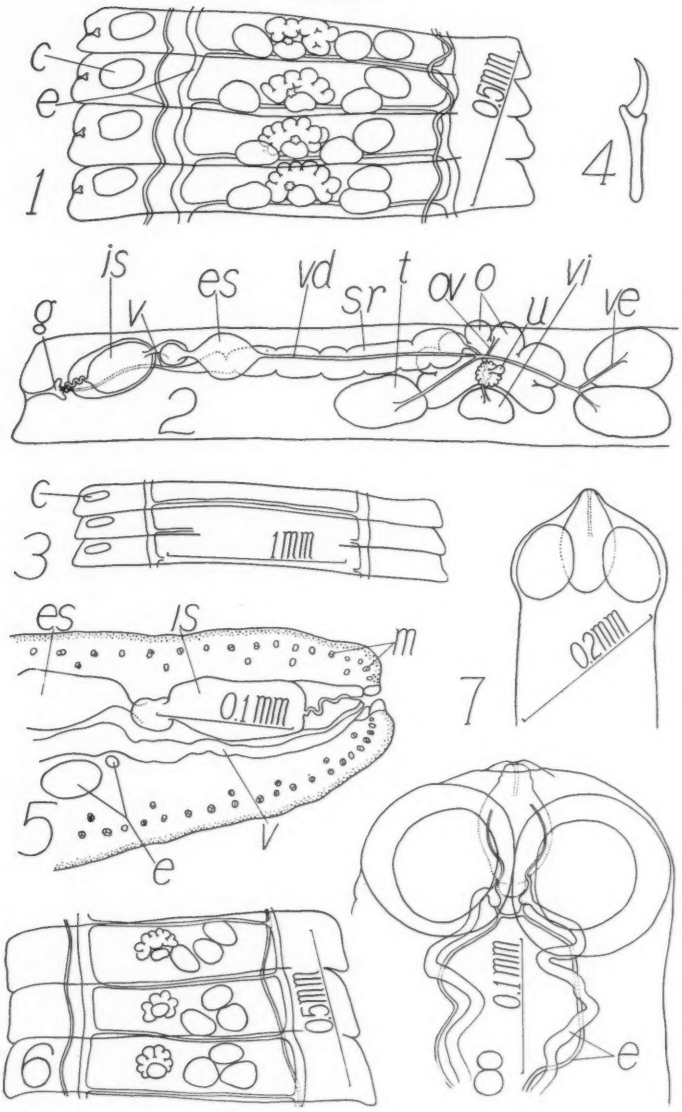
PLATE 1

All figures concern *Hymenolepis scalopi* n. sp. and with the exception of figures 2 and 4 were drawn with the aid of a camera lucida. Abbreviations: c — cirrus pouch, e — excretory canals (ventral the larger), es — external seminal vesicle, g — genital atrium, is — internal seminal vesicle, m — deep longitudinal muscles, o — ovary, ov — oviduct, sr — seminal receptacle, t — testis, u — uterus, v — vagina, vd — vas deferens, ve — vas efferens, vi — vitellarium.

FIGURES

1. Mature proglottides, dorsal view.
2. Diagram of mature reproductive system.
3. Gravid proglottides, outline sketch.
4. Hook of oncosphere.
5. Portion of cross section through cirrus pouch and vagina.
6. Successive proglottides showing aberrant arrangement of testes.
7. and 8. Two different scoleces showing variation in relative sizes of rostellum and suckers.

PLATE I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North American Rhabdocoela and Alloeocoela—IV.

Mesostoma macropenis, New Species, from Douglas Lake, Michigan

Libbie H. Hyman

A collection of rhabdocoels from Douglas Lake, Michigan, kindly sent to me for identification by Mr. George Moore, of the zoology department of the University of Michigan, consisted, in addition to *Gyratrix hermaphroditus hermaphroditis*, stated by Mr. Moore to be the most common rhabdocoel in Douglas Lake (apart from *Stenostomum*, one supposes), of species of *Macrostomum, Microstomum, Dallyellia*, and *Mesostoma*. While probably most of these forms were new species, the material sufficed only for a determination of the *Mesostoma*, which is herein described.

Until recent years, the large and characteristic genus *Mesostoma* was known from North America only by *M. ehrenbergii*, which is probably widespread throughout the continent and which I found several times in the vicinity of Chicago. It is certain, however, that many more species of the genus must exist in the fresh waters of the United States. Recently, Kepner, Ferguson, and Stirewalt (1938) have described *Mesostoma virginiana* from a spring-fed swamp in the Blue Ridge Mountains of Virginia, at an altitude of 3,500 feet. I have studied and described another new species, *Mesostoma arctica* (Hyman, 1938), the first material of which came from temporary pools on the tundra in northern Canada near the Arctic Circle. Later additional specimens of this same species were taken in a willow bog at 10,500 feet elevation in the Medicine Bow Mountains of Wyoming. The Douglas Lake *Mesostoma* is thus the fourth member of the genus to be described from North America.

Mesostoma macropenis sp. nov.

Figs. 1-4.

Description.—The body is of short fusiform shape, probably 1.5 mm. or more in length when fully extended, colorless and transparent with a dark middorsal strand from the eyes back to the level of the rear end of the gut. The general appearance of the animal and the location of the principal structures are given in Fig. 1, constructed from whole mounts and sections with the aid of a sketch from life sent by Mr. Moore. There is no anterior pit or depression such as occurs in several species of *Mesostoma*, including *M. arctica*. A pair of eyes was indicated by Mr. Moore but was not detectable in the preserved material. No rhabdite-tracts were noticeable. From the brain the usual two nerve trunks, easily seen in life, extend forward branching extensively to the anterior margin of the body. In the rear end behind the gut a clear area occurs in the living animal, according to Mr. Moore, but was not evident in the preserved specimens. The typical rosette pharynx occupies a

position anterior to the middle. The gut is of the shape characteristic of the genus extending as a simple cylinder anteriorly in front of the pharnyx as far as the brain and posteriorly to the clear area above mentioned which occupies about the posterior fifth of the animals's length.

The fixation of some of the specimens is exceptionally good but the histology does not appear to present anything of especial interest. The epidermis appears to be syncytial, has large nuclei, and is packed peripherally with small rhabdites. A few rhamnites also occur. Beneath the epidermis there is a definite basement membrane, immediately internal to which is located the subepidermal musculature, consisting of an outer circular and an inner longitudinal stratum.

The details of the reproductive system constitute the main basis for taxonomic distinctions in rhabdocoels. That of *M. macropenis* follows the plan typical of the genus. The testes are a pair of elongated lobulated bodies lying dorsally in the lateral regions. Ventral to them are seen the rounded deeply staining follicles of the yolk gland on each side (Fig. 1). The connections of testes and yolk glands with the copulatory complex were not traced. The copulatory complex has a characteristic construction in the genus *Mesostoma*. All its parts spring from the dorsal and lateral walls of a large common genital chamber or atrium situated directly behind the pharynx. The male complex arises on the left, the copulatory bursa in the center, and the rest of the female complex on the right. The two uteri are lateral in position coming from the latero-posterior surfaces of the atrium. Because of the overlapping of the parts in saggital view, the male and female complexes are here represented separately (Figs. 2 and 3).

In *M. macropenis* the common genital pore is separate from and a little distance behind the mouth (Fig. 2). It opens dorsally by a narrow passage into the common genital atrium which in this species contains the relatively large penis papilla (Figs. 3 and 4). The common vas deferens, expanded into an external seminal vesicle, passes anteriorly to near the rear wall of the pharynx, then narrows abruptly, bends ventrally and backwards and opens into the large oval seminal veiscle, packed with sperm (Fig. 2). The long axis of this lies approximately in the body axis. At its posterior end it narrows and then opens into the smaller oval granule or prostate vesicle. In *M. macropenis* the seminal vesicle and prostate vesicle are distinct, as also in *M. arctica*, while in most species of *Mesostoma* they are fused into one common vesicle. At the junction of seminal vesicle and granule vesicle a cluster of granule glands opens into the latter by way of long necks. The interior of the granule vesicle contains a central passage for the sperm encircled by long chambers which house the eosinophilous secretion of the granule glands. The granule vesicle parallels the seminal vesicle but is directed forward and terminates in the large bulging penis papilla which about half fills the cavity of the genital atrium (Fig. 3). The penis papilla consists of a loose reticular tissue clothed with a syncytial epithelium. Inside it the ejaculatory duct, asymmetrically placed, continues from the granule vesicle as a narrow duct which curves ventrally and then

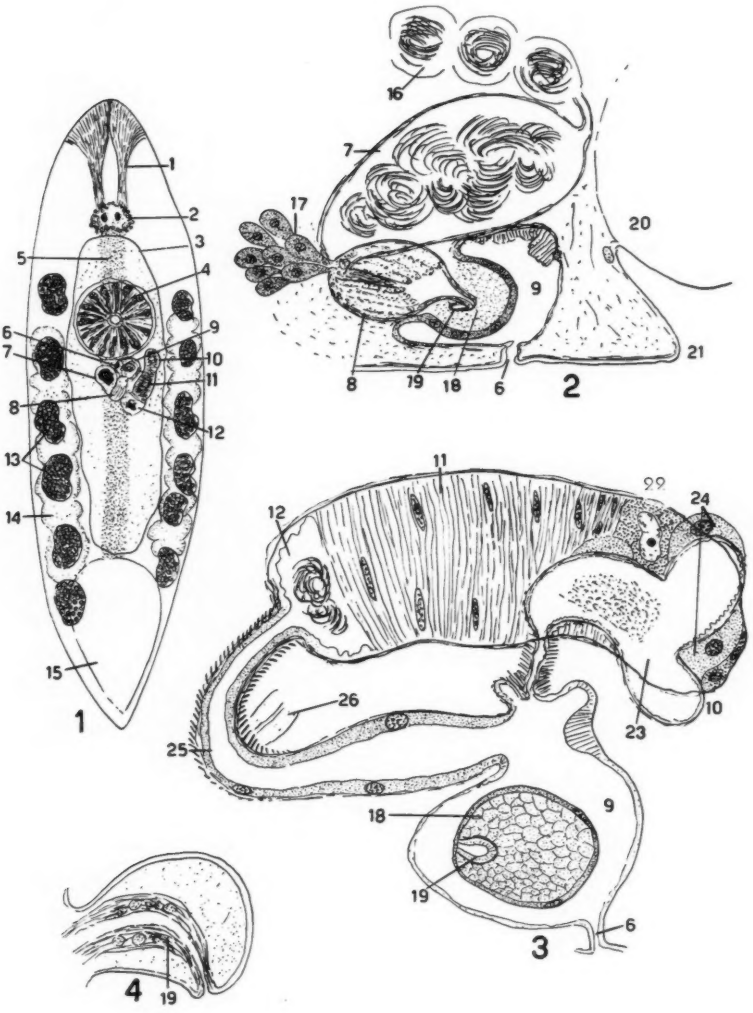
EXPLANATION OF PLATE

Fig. 1. Dorsal view of *Mesostoma macropenis*, shape from a sketch from life by Mr. Moore, details added from stained whole mounts and sections. The yolk glands are viewed through the testes.

Fig. 2. Sagittal section of the male portion of the copulatory complex.

Fig. 3. Sagittal view of the female portion of the copulatory complex; the copulatory bursa is on the other side of the ovary, details of which have been omitted at this place to show the bursa.

Fig. 4. The penis papilla in sagittal section from a frontal series. 1, main anterior nerves; 2, brain; 3, intestine; 4, pharynx; 5, middorsal dark stripe; 6, genital pore; 7, seminal vesicle; 8, granule vesicle; 9, genital atrium; 10, ovary; 11, oviduct; 12, seminal receptacle; 13, yolk glands; 14, testes; 15, posterior clear area; 16, common vas deferens; 17, cluster of granule glands; 18, penis papilla; 19, ejaculatory duct; 20, pharynx; 21, mouth; 22, ovocytes; 23, copulatory bursa; 24, gland cells of same; 25, common female duct; 26, yolk duct.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opens. As the penis papilla lies somewhat transverse to the body axis one does not get a good idea of its shape from sagittal sections. A sagittal view of the penis from a series of frontal sections is shown in Fig. 4. The curved beak-like shape is diagnostic of the species.

The female part of the copulatory complex consists as usual in the genus of a median copulatory bursa and the main female system to the right. The copulatory bursa (Fig. 3) is an irregular sac which opens into the dorsal wall of the common genital atrium by a slender muscular stalk. The main female organs form one continuous stalked structure (Fig. 3). This begins with the ovary situated close to the pharynx and containing a succession of ovocytes, youngest at the free tip, increasing in age and size towards the oviduct. The ovary continues without boundary into the broad oviduct composed of flat thin disk-like cells as usual in *Mesostoma*. Ordinarily no lumen is present in the oviduct. Distal to the oviduct is a chamber, the seminal receptacle, usually containing a mass of sperm. The female system then narrows into the common female duct, provided at first with a muscular wall. The common duct curves ventrally, then turns anteriorly paralleling the oviduct and opens into the dorsal wall of the atrium, behind the opening of the copulatory bursa. At the bend, the common duct receives on its anterior surface the vitelline duct from the yolk glands. This proceeds dorsally where it presumably forks to the yolk glands.

The uteri, not shown in any of the figures, are paired channels with indefinite walls. Each extends laterally from the posterolateral walls of the common genital atrium and then divides into an anterior and a posterior branch. The combined uteri thus have an H-shape as in *M. ehrenbergii*. The available specimens were not fully ripe and the uterine branches did not extend very far before or behind the atrium. Presumably when the dormant eggs are in process of formation, the uteri expand.

Differential diagnosis.—Colorless, simple spindle shape, no rhabdite tracts, copulatory bursa an irregular sac, combined uteri H-shaped, large seminal vesicle separate and distinct from the granule vesicle, penis papilla very large, bulging into atrium, ejaculatory duct inside the papilla curved and asymmetrically placed, genital pore separate from the mouth.

Locality.—South Fishtail Bay, Douglas Lake, Michigan, 4-10 meters depth, sandy bottom. Collected July, August, 1937, by George M. Moore.

Holotype.—One set of sagittal serial sections; paratype, one whole mount; in the author's collection.

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Cercariae Infecting Pomatiopsis lapidaria Say*

Donald J. Ameel

The amphibious snail, *Pomatiopsis lapidaria,* first came to my attention when I (Ameel, 1932) discovered it to be the first intermediate host of *Paragonimus kellicotti.* During the study of *Cercaria P. kellicotti,* four other cercariae were discovered infecting this snail and observations on their morphology and life histories were made. One of these, a heterophyid cercaria, penetrated frogs and tadpoles. When fed to rats, adult heterophyids identified as normally infecting the mink were recovered. The adult fluke was described and named *Euryhelmis monorchis* Ameel, 1938 which established the name *Cercaria E. monorchis* for the cercaria. The three remaining cercariae are described in this paper.

The majority of the snails were collected in the Huron River drainage in the neighborhood of Ann Arbor, Michigan, but small collections were also made at Newport and Muskegon, Michigan. The snails were placed in small bottles containing water which were examined for several days for the emerged cercariae. Many snails were crushed also in order that a complete study could be made. The percentage of occurrence given for each species is based on those that emerged normally. *Intra vitam* stains were used, of which neutral red, nile blue sulphate and methyl green were the most satisfactory.

Acknowledgement is due Dr. George R. La Rue who made this study possible.

Cercaria pomatiopsidis

Stimpson (1865) obviously described this cercaria. He found it frequently in the course of a study of the anatomy of *P. lapidaria.* Although his description and figure were superficial, it is evident that he saw the species described below. He gave it the name *Histrionella pomatiopsidis.* The new combination is *Cercaria pomatiopsidis.*

Cercaria pomatiopsidis (Fig. 3) occurred in 1.3 per cent of the snails collected. It is an ophthalmoxiphidiocercaria with a small stylet. They are active swimmers which are positively phototropic when they emerge but soon react negatively.

The ventral sucker is slightly larger than the oral. Several rows of small spines are present on its inner edge. The pharynx impinges on the oral sucker. The long esophagus extends to the ventral sucker. Other details of the digestive tract could not be observed. A butterfly-shaped ganglionic mass is located

* Contribution of the Department of Zoology and the Biological Station of the University of Michigan.

between the eyespots. The five pairs of penetration glands are immediately anterior or somewhat lateral to the ventral sucker. Their ducts are lateral. The genital primordium is dorsal to the ventral sucker and may extend beyond its anterior and lateral edges. The excretory bladder is made up of four, rarely five, chambers of which the posterior is the largest and has the thinnest wall. The entire region lateral to the bladder is filled with large cells containing granular globules which stain heavily with neutral red. There are six pairs of flame cells arranged according to the formula 2[(2+2+2)+(2+2+2)].

Measurements of ten cercariae fixed in hot 10 per cent formalin are as follows: body, 0.180-0.200 mm. (av. 0.193 mm.) long by 0.070-0.080 mm. (av. 0.074 mm.) wide; tail, 0.220-0.240 mm. (av. 0.225 mm.) long by 0.030 mm. wide at the base; oral sucker, 0.032-0.035 mm. (av. 0.033 mm.) by 0.032-0.033 mm. (av. 0.032 mm.); stylet about 0.008 by 0.004 mm.; pharynx about 0.008 by 0.008 mm.; ventral sucker, 0.032-0.036 mm. (av. 0.033 mm.) by 0.038-0.040 mm. (av. 0.039 mm.).

The rediae are elongate, relatively inactive and may contain a dozen or more developing cercariae. The mouth is terminal, the pharynx muscular and more or less spherical. The gut is small, rather spherical, and is filled with amber colored food particles. It is confined to the anterior eighth of the body.

Ten rediae killed in hot ten percent formalin measured 0.350-0.720 mm. (av. 0.511 mm.) by 0.110-0.160 mm. (av. 0.147 mm.). The pharynx measured 0.022-0.032 mm. by 0.025-0.032 mm. (av. 0.028 by 0.030 mm.) and the gut 0.016-0.028 mm. by 0.028-0.048 mm. (av. 0.022 by 0.039 mm.).

Superficially *Cercaria pomatiopsidis* suggests the cercariae of the Allocreadiidae as exemplified by *Cercaria Crepidostomum cooperi* Hopkins, 1934 and *Cercaria C. cornutum* Ameel, 1937. *Cercaria pomatiopsidis* differs fundamentally from these species in that (1) the stylet is much smaller (2) the pharynx impinges on the oral sucker (3) there is a complete absence of their type of cystogenous glands (4) the suckers are not fringed with papillae (5) there is a greater number of penetration glands, and (6) the bladder is more complex.

Cercaria geddesi sp. nov.

Cercaria geddesi (Fig. 1) is a xiphidiocercaria which was present in 13.4 per cent of the snails collected. The cercariae often emerged in great numbers and were positively phototropic. Brief periods of swimming alternated with prolonged periods of creeping on the substratum. When swimming, the tail is longer than the body but at other times it is somewhat contracted to about one half the length of the body. The body is spinose. Minute spines also were observed on the basal part of the tail. A large virgula is located in the oral sucker. A poorly defined pharynx somewhat removed from the oral sucker is the only evidence of the digestive tract posterior to the sucker. Many small pyriform cystogenous glands are distributed between the pharynx and posterior end of the body but are most numerous posterior to the ventral sucker. The four pairs of penetration glands are lateral to the sucker. Three

pairs of ducts are lateral and the fourth pair median. The genital primordium is a large irregular mass dorsal and posterior to the ventral sucker. The excretory bladder is large and V-shaped. There are five pairs of flame cells whose ducts were not detected. The ganglionic mass is between the oral sucker and and acetabulum.

Measurements of ten cercariae fixed in hot 10 per cent formalin are as follows: body, 0.144-0.157 mm. (av. 0.150 mm.) long by 0.067-0.083 mm. (av. 0.071 mm.) wide; tail, 0.088- 0.120 mm. (av. 0.101 mm.) long by 0.019-0.024 mm. (av. 0.021 mm.) wide at the base; oral sucker, 0.041-0.048 mm. (av. 0.044 mm.) by 0.036-0.043 mm. (av. 0.040 mm.); stylet about 0.024 by 0.006 mm.; pharynx about 0.011 by 0.011 mm.; ventral sucker, 0.024-0.027 mm. (av. 0.024 mm.) by 0.024-0.027 mm. (av. 0.024 mm.).

The sporocysts are small, oval or rounded, and occur in large numbers in the liver arranged in elongate clusters. Ten living sporocysts containing well developed cercariae slightly flattened under the cover slip measured 0.230-0.450 mm. (av. 0.326 mm.) long by 0.150-0.200 mm. (av. 0.180 mm.) wide.

Cercaria geddesi by virtue of its virgula belongs in the Cercariae virgulae group of cercariae established by Lühe (1909). It closely resembles *Cercaria nodulosa*, v. Linst. as described by Wesenberg-Lund (1934). The number of penetration glands is the same and the arrangement of the glands and ducts is similar. However, *Cercaria geddesi* is considerably smaller.

Cercaria marilli sp. nov.

Cercaria marilli (Fig. 4) is a trioculate monostome cercaria which occurred in 1.2 per cent of the snails collected. Both the body and tail are capable of considerable extension and contraction. Active cercariae measured: body, extended, 0.42 mm., contracted, 0.21 mm.; tail, extended, 0.56 mm., contracted, 0.28 mm.

Naturally emerged cercariae have three eye-spots. The pigmented lateral eye-spots are conical and possess a lens. The median eye-spot is light brown and consists of a diffuse mass of pigment granules.

The body is opaque and filled with brown colored pigment granules and cystogenous cells packed with rod-like cystogenous material. The pigment granules form a network over the body being concentrated in the anterior region. My data, taken when this study was made several years ago, indicates that there is no well defined condensation of pigment into dorsal or ventral longitudinal bands such as has been described in many monostome cercariae. However, further study will be necessary when material becomes available to establish definitely this observation. Posterolateral locomotor organs are present. They are spineless.

The intestinal bifurcation occurs in the anterior third of the body. The ceca

are medial to the excretory trunks, terminating posterior to the genital primordium. The bulk of the genital primordium is immediately anterior to the excretory bladder. No detailed study of the genital system was made.

The excretory system is similar to that of other monostome cercariae. Two lateral excretory trunks filled with large excretory granules extend anteriorly from the relatively small excretory bladder and join just behind the median eye-spot where there is a short blind median pouch. The excretory pore opens at the junction of tail and body. A median excretory tube from the bladder terminates blindly near the tip of the tail. The system of excretory tubules and flame cells was not observed but the short branch into which they open was discerned near the middle of each excretory trunk.

The anterior ganglionic mass lies at the level of the eye-spots. Short branches extend to the eye-spots. Two nerves proceed anteriorly to the lateral edges of the oral sucker and two large lateral nerve trunks proceed posteriorly in the neighborhood of the excretory trunks.

Measurements of ten cercariae fixed in hot 10 per cent formalin are as follows: body, 0.240-0.300 mm. (av. 0.276 mm.) long by 0.130-0.200 mm. (av. 0.165 mm.) wide; tail, 0.210-0.350 mm. (av. 0.268 mm.) long by 0.07 mm. wide at the base; oral sucker, 0.033-0.040 mm. (av. 0.036 mm.) by 0.032-0.040 mm. (av. 0.035 mm.).

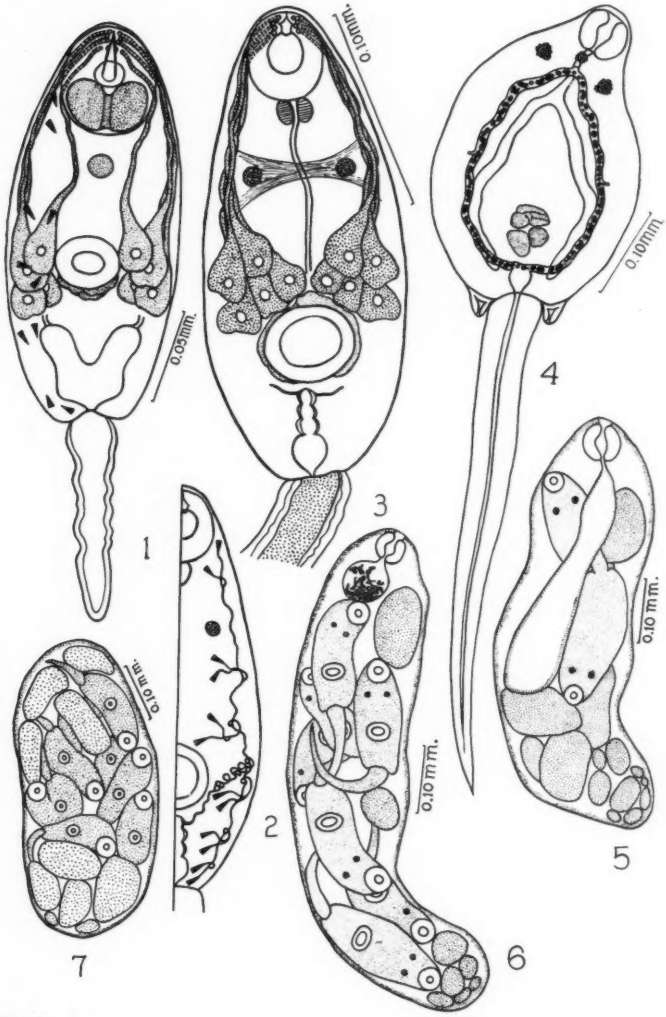
Generally the cercariae emerge in relatively small numbers and encyst after a brief period of activity. At times many of the cercariae fail to encyst and are found lying dead upon the bottom of the dish. The elevated portion of the cyst of ten unflattened specimens measured 0.112-0.126 mm. (av. 0.117 mm.) and the basal disc 0.168-0.182 mm. (av. 0.176 mm.) in diameter.

The simple sac-like rediae are pigmented and are capable of considerable extension and contraction. The mouth is terminal opening immediately into a muscular pharynx. The gut is moderately voluminous and long, extending to the posterior third of the body. It is filled with reddish brown food particles.

The body cavity is filled with germ balls in various stages of development and seldom more than two to four cercariae which lack the median eye-spot. The cercariae escape into the liver of the snail where development is completed. The median eye-spot is formed and there is an increase in size and pigmentation.

Ten rediae containing cercariae killed in hot per cent formalin measured: body, 0.630-1.020 mm. (av. 0.847 mm.) by 0.200-0.300 mm. (av. 0.245 mm.); pharynx, 0.040- 0.046 mm. (av. 0.043 mm.) by 0.040-0.046 mm. (av. 0.043 mm.); gut, 0.250-0.450 mm. (av. 0.378 mm.) by 0.080-0.100 mm. (av. 0.097 mm.).

Cercaria marilli closely resembles *Cercaria urbanensis* Cort in structure. *Cercaria marilli* is smaller and probably differs in the arrangement of its pig-



FIGURES

1. *Cercaria geddesi.*
2. *Cercaria pomatiopsidis,* excretory system.
3. *Cercaria pomatiopsidis.*
4. *Cercaria marilli.*
5. Redia of *Cercaria marilli.*
6. Redia of *Cercaria pomatopsidis.*

ment granules. The rediae are of about the same size but the pharynx and gut of *Cercaria marilli* are somewhat smaller. Luttermoser (1935) recovered adult *Notocotylus urbanensis* from a duckling fed encysted *Cercaria urbanensis*. Two ducklings fed large numbers of encysted *Cercaria marilli* by me were negative when examined after 16 days.

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Entonyssus ewingi n. sp., an Ophidian Lung Mite*

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A female rattlesnake (3.5 feet long), *Crotalus cinereous* Le Conte in Hallowell 1852, captured April 28, 1938 near "Salt Creek Canyon" about nine miles northwest of Hitchcock, Oklahoma, harbored 11 lung mites representing an apparently new species of Dermanyssidae. The name *Entonyssus ewingi* is proposed for this form.

The mites, fixed in hot Bouin's fluid, preserved in 70 percent alcohol, cleared in glycerolactophenol (Magath 1916), and temporarily mounted in glycerine for study, appeared to be all females. Eight of them were large, nearly uniform in size and structure, and contained each a large embryo clearly visible in the opisthosoma (Fig. 2). The other three were considerably smaller.

Entonyssus ewingi sp. nov.

Description of female.—General form (Figs. 2 and 3) and anatomy typical. Color white, somewhat translucent. Fresh specimens were blotched with broad streaks of red, brown, and orange, mistaken at first for pigmentation in the skin but later attributed to presence of blood in digestive tract. Body proper elongate, roughly ovoidal with smaller end forward, slightly compressed dorsoventrally, slightly constricted anteriar to middle at level of legs IV, widest in opisthosoma, about half as wide as long.

Chitinous shields of trunk include the dorsal, sternal, genitoventral, and anal plates. Endopodal and tritosternal plates lacking. Exposed areas of skin finely wrinkled in a complex pattern suggestive of fingerprint markings. Dorsal shield single, longitudinally elongate, somewhat ovoidal with smaller end cephalad, slightly narrowed at the above-mentioned constriction, located nearer front end. Bare skin exposed on all sides of shield. Dorsal shield armed with about 17 pairs of short stout articulate spines of two rather distinct sizes, distribution being more sparse at middle of shield than toward ends. Larger spines located chiefly anteriad, smaller ones all posteriad. Pattern of paired spines not precisely symmetrical. Sternal plate at level of coxae II and III, with 3 pairs of large spines. Genitoventral plate small, slightly caudad to coxae IV; two pairs of spines (one large and one small) situated anteriorly on ventral side of opisthosoma vary as to their distribution on or near plate. Anal plate broadly ellipsoidal, longitudinally elongate, 3-spined. In addition

* A contribution from the Zoological Laboratory, Oklahoma Agricultural and Mechanical College, prepared under the direction of R. Chester Hughes.

The new species is named in honor of Dr. H. E. Ewing of the United States National Museum, by whom the genus *Entonyssus* was originally described.

Identification of the rattlesnake was confirmed by Dr. Charles E. Burt of Southwestern College, Winfield, Kansas.

to spines already mentioned, bare skin of trunk bears a pair (large) immediately anterior to spiracles, 2 pairs (large) on dorsal surface of opisthosoma —one pair being anteromesad to other, and about 4 pairs (3 large and 1 small) variously arranged on ventral side of opisthosoma.

Spiracles (Figs. 3 and 9) lateral; dorsal to coxae IV; dome-like, each subdivided by a constriction into distal and proximal annuli, former much smaller than latter, presenting appearance of a small flat bead resting on a larger one. Trachea, leading inward from spiracle, chitinized for a short distance.

Capitula of typical form, continuously surrounded transversely by a chitinous shell with dorsal and ventral anterior extensions (labrum and labium). Labrum (Fig. 14) roughly semi-octagonal although transversely elongate, with smoothly sinuous anterior margin, pair of shorter fimbriate anterolateral margins, and still shorter, comparatively straight, lateral sides that are very slightly convergent posteriad; all margins gently down-curved.

Labium (Fig. 13) of intricate form; almost completely split into two by a narrow median anterior cleft; each half subdivided anteriorly into three lobes—medial, middle, and lateral; medial lobe the most narrow and elongate, with broad base; lateral lobe the most heavily chitinized, paddle-shaped, with narrow articulate base; middle lobe very broad, overlapping the other two ventrally, extending not so far forward, and much less narrowly pointed, bears a very prominent hair-like spine and a small anterolateral tooth-like marginal process. Slightly posteriad to the median cleft the labium bears two pairs of short stout spines arranged in a nearly transverse row—the two spines on either side close together and far from those on the other. Located posteriad to angles where the labium becomes contiguous with capitula, exoskeleton bears a pair of very prominent longitudinally elongate internal tuberosities of irregular form, each roughly subdivided into a large elongate medial lobe and a small hemispherical posterolateral knob.

Chelicerae (Figs. 1 and 13) stout, well developed, provided with chitinized basal sheaths. Form of chelae almost indescribably complex. Fixed chela overlies and anteriorly overlaps movable one. Opposed chelae (Figs. 7 and 12) somewhat resemble the mandibles of a bird, each having a concavity bounded by thin side walls—the medial and lateral *alae*. Alae on each chela dissimilar in size and shape. Roof of dorsal (fixed) chela and floor of ventral (movable) chela, between their respective alae, more heavily chitinized and each extends forward beyond alae to form a distinct tip. Tip of dorsal chela abruptly recurved ventrally, with a ventrosubterminal enlargement and a sharp posteriorly directed point (Figs. 1 and 7)—recurvature so abrupt that front end of chela is also somewhat pointed. On dorsal chela, medial ala wider; on ventral, lateral wider. Lateral ala of dorsal chela has an articulate finger-like process opposite a longitudinally elongate "keyhole" in lateral ala of ventral chela (Fig. 12). In closing together, chelae interlock with tip of ventral medially overlapping tip of dorsal and with one ala of each (lateral on dorsal, medial on ventral) fitting between both alae of other and with above-mentioned finger-like process fitting into said keyhole. Middle joint of chelicera

bears a dorsolateral articulate spine at base of fixed chela and a fringe of filamentous processes on its free anteroventral margin enclosing base of movable chela (Figs. 7 and 12).

Hypostome (Fig. 8) a much-depressed hollow cone, apex forward, with oblique ovoidal mouth opening directed dorsosubanteriad. Floor of hypostome about twice as long as roof, extends anteriad beyond mouth to a sharp point. Hypostome covered internally and externally with slender forward-pointing filamentous processes—most prominent upon roof and least noticeable inside roof. Roof marked by Y-shaped thickening—stem of Y being posteriad and short, limbs narrowly divergent and gently out-bowed.

Legs (Fig. 10) nearly uniform in size (II being slightly shortest and IV a little more distinctly longest) and similar in structure except for special features of tarsus I discussed below. All tarsi provided with prominent claws (Fig. 4), "claw bars," and well-developed pulvilli. Tarsal claws, stout, somewhat L-shaped, with heavy rounded bases and straight sharp-pointed tips. Claw bar (a cross-piece articulate with bases of the two claws), of intricate but definite shape, has a pair of fossae that house bases of claws and a prominent midventral boss. Pulvillus (Fig. 4) with a dorsal, somewhat semihexagonal lobe and a pair of ventral, basally contiguous, digitiform processes. Legs all provided with articulate spines of variable size and proportions but mostly short and stout except on tarsus I, and of general distribution although most abundant on proximal segments of tarsi and lacking entirely on their distal segments and apparently on coxae III. Legs all 7-jointed (counting both tarsal segments). All femora and basal segments of tarsi II, III, and IV have short proximal pseudojoints. Spination of opposed appendages approximately symmetrical.

Tarsus I (Fig. 6) differs from the others in that its basal segment is relatively larger, more nearly cylindrical, without a pseudojoint, and provided with larger spines and certain characteristic irregularities in shape. Articulate spines, although of variable proportions, all more elongate and more hair-like than on any other leg segments. One particularly prominent spine projects dorsodistad from distal end of segment on dorsal side. Irregularities in shape include (1) a somewhat sinuous groove on lateral aspect of distal half, (2) a transverse groove across dorsal side near distal end, (3) about 6 nonarticulate, somewhat cylindrical, terminally blunt, processes scattered on dorsal side near distal end—most prominent one of these projecting backward over above-mentioned transverse groove, and (4) a ventroterminal indentation which houses base of distal segment. Length ratio of tarsus I to tibia I about 2+.

Palpus (Fig. 11) 5-jointed; distal segment much the smallest and provided with 2 spines—one of them terminal, very prominent, about 3 times as long as the segment; penultimate segment longer than antepenultimate, provided with about 14 spines of various sizes—one distomesad spine very stout and containing a conspicuous basal cavity (Figs. 11 and 13); other segments (proceeding proximad) provided with about 6, 4, and 2 spines respectively.

Average measurement in microns from 5 of the larger specimens (pre-

served). L=length, W=width at widest point. Total L 1240. Trunk, L 970, W. 530. Tarsi (D=length of distal segment): I—L 213, W 43, D 43; II—L 213, W 53, D 64; III—L 213, W 50, D 53; IV—L 298, W 43, D 55. Tibia I—L 96, W 43. Tibia II—L 70, W 55. Palpus L 117. Claws —L of point 15, L of base 23. Spiracle—outside diameter 10.5.

The above-mentioned small specimens, scarcely half as large as the big ones, with the exoskeleton much more thinly chitinized and the opisthosoma relatively smaller, are in general agreement with the large ones in regard to the form of the mouth parts, the distribution of chitinous plates, spines, and processes, and in the general shape and proportions of the joints of the several appendages. They are presumed to be young females.

Male.—Unknown.

Host.—*Crotalus cinereous* Le Conte in Hallowell 1852.

Habitat.—Air sac and trachea.

Locality.—"Salt Creek Canyon" near Hitchcock, Oklahoma.

Type specimens.—Three cotype specimens mounted *in toto*, in the United States National Museum.

Discussion

The list of known ophidian dermanyssid lung mites with their respective hosts now includes (1) the type species *Entonyssus halli* Ewing 1922 from a

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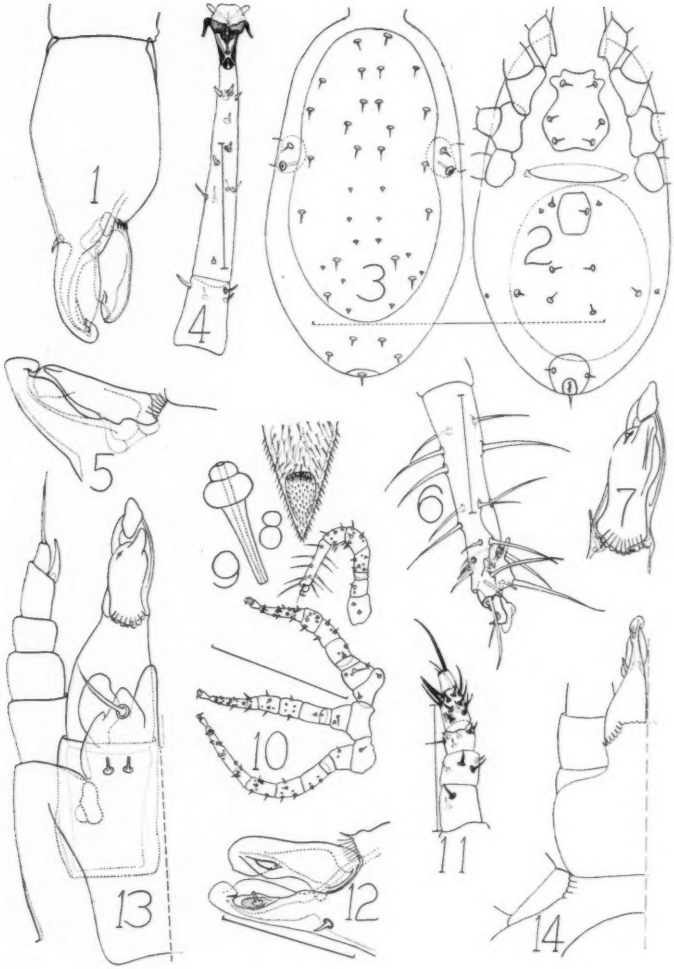
EXPLANATION OF PLATE

All figures concern *Entonyssus ewingi* n. sp. and were made from adult females. Figures 1, 5, 7, and 9 are freehand studies—the others were drawn with the aid of a camera lucida with minor details added freehandedly.

FIGURES

1. Right chelicera, ventral view.
2. Trunk, ventral view, shows sternal, genitoventral, and anal plates. Broken line in opisthosoma shows outline of an embryo. Scale=1 mm.
3. Trunk, dorsal view. Shows dorsal shield and location of spiracles dorsal to coxae IV. Scale=1 mm.
4. Left tarsus III, ventral view. Scale=0.1 mm.
5. Left chelicera, medioventral view.
6. Right tarsus I, lateral view.
7. Right chelicera, ventral view.
8. Hypostome, dorsal view. Shows oblique dorsosubanteriad mouth opening and the covering of filamentous processes on both the internal and external surfaces.
9. Spiracle and peritreme—outer end up.
10. Right legs, ventral view. Leg I is shifted forward out of its natural position in relation to the others. Scale=0.5 mm.
11. Left palpus, ventral view. Scale=0.1 mm.
12. Left chelae, lateral view. Shows their interlocking concavities each bounded by dissimilar alae and how the movable finger on the dorsal fixed chela fits into a "keyhole" in the other. Scale=0.05 mm.
13. Labium, right half, ventral view.
14. Left chelicera and left half of labrum, dorsal view. Notice undulate anterior margin and fimbriate anterolateral margin of labrum—also the dorsal longitudinal midridge and medial ala of the fixed chela. The lateral ala of ventral movable chela is visible at the left.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"Pine snake," (2) *Entonyssus rileyi* Ewing 1924 from a "Rattlesnake from Texas," (3) *Entonyssus glassmacheri* Vitzthum 1935 from "einem nordamerikanischen *Coluber quadrivittatus* Holbrook aus dem Berliner Aquarium," (4) *Ophiopneumicola colubri* Hubbard 1938 from *Coluber flagellum flavi-gularis* (Hallowell), and (5)*Entonyssus ewingi* n. sp. from *Crotalus cinereous* Le Conte in Hallowell. So far as I know lung mites have not been found in other reptiles.

The chelae, in the present form, with their interlocking concavities each bounded by dissimilar alae and with the movable finger of one fitting into a "keyhole" of the other, are distinctly more complex than those figured in the several original descriptions of *E. halli, E. glassmacheri,* and *O. colubri.* A satisfactory comparison in this respect with *E. rileyi* is impossible since the chelae, not illustrated, were described merely thus—". . . fixed arm harpoon-like and extending beyond the movable arm by the width of the ventral distal process; movable arm stouter than the fixed arm, almost straight, and with a rough cutting edge."

It is quite possible that the present species is identical with *E. rileyi,* the very brief description (Ewing 1924) of which was based on the study of a single female specimen. For the most part that description "fits" the present form but it fails entirely to account for much of the detail observed in my specimens. *E. rileyi* seems to differ from *E. ewingi,* however, in having (1) the chelae apparently more simple and with the "moveable arm stouter . . . than the fixed . . .," (2) the "abdomen . . . naked," and (3) a smaller length-ratio (1.5) of tarsus I to tibia I—the ratio is 2+ in my specimens.

The female of *E. ewingi* differs from the very briefly described female of *E. halli* in having (1) a much larger size, (2) chelae of much more complex form, and (3) the spiracles located farther posteriad; from the very fully described *E. glassmacheri* in (1) being somewhat larger, (2) the more complex form of the chelae, (3) having more spines on the naked skin of the trunk (both dorsally and ventrally) and fewer on the dorsal shield, (4) lacking the pair of very prominent posteromarginal spines of the dorsal shield, (5) lacking the midventral suture of the capitular shell, and (6) lacking the tritosternum.

It is noteworthy that *E. glassmacheri* is the only one of the 5 above mentioned mites for which the male is definitely known.

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An Annotated List of the Species of Jassinae Known to Occur in Indiana (Homoptera, Cicadellidae)[1]

Harry E. Brown

Only fourteen species of the sub-family Jassinae have been reported heretofore as occurring in Indiana. Five of these *(Platymoideus acutus, Scaphoideus immistus, Norvellina seminudus, Sanctanus sanctus, Colladonus clitellarius)* were described by Say (3) in 1831 from Indiana specimens. In addition to these Van Duzee (4) has recorded *Polyamia inimicus, Amplicephalus osborni, Exitianus obscurinervis, Eutettix pictus* and *Macrosteles divisus,* Lawson (2) *Driotura gammaroides,* Davidson and DeLong (1) *Balclutha impicta,* and Shaw (4) *Parabolocratus major.*

The present list adds 106 species and one variety, making a total of 120 species and one variety, distributed in 52 genera, known to occur in Indiana.

Over half of the described species of North American leafhoppers are included in the sub-family Jassinae, making it an important group from a taxonomic standpoint. From the standpoint of economic importance the subfamily also ranks high, containing such recognized pests of the cereals and pasture lands as *Polyamia inimicus, Exitianus obscurinervis, Phlepsius irroratus* and *Unerus nigrifrons. Macrosteles divisus,* an important vector of the Aster yellows, and *Norvellina tenellus,* the beet leafhopper, also belong in this sub-family.

For a long time leafhoppers were considered to be secondary in importance as pests, for it was hard to accredit much significance to such small creatures; but at the present time they are considered to be the wost insect pests of grasslands and of no little importance as pests of cereals, orchard trees and other special crops.

The material upon which this list is based was collected by the writer and various other collectors during the past three years, with the exception of a few specimens taken in general collecting before that time, and Mr. W. J. Gerhard's material, most of which was collected thirty or more years ago. Specimens of all species examined are deposited in the Purdue Entomological Collection.

To Mr. P. W. Oman of the U. S. National Museum, who very kindly checked many of the writer's identifications: to Mr. W. J. Gerhard, curator of Entomology at the Field Museum of Natural History in Chicago, for the generous loan of specimens from his private collection; and especially to Dr.

1 The data here presented were gathered by the writer during the preparation of his undergraduate thesis at Purdue University. Contribution from the Entomological laboratories of Purdue University.

Howard O. Deay of Purdue University for his helpful suggestions and assistance during the course of this study, the writer wishes to express his gratitude.

The photographs represent genera typical of the sub-family.

Species marked with an asterisk have been reported heretofore from Indiana.

Sub-family JASSINAE A. & S., 1843

Tribe ACUCEPHALINI Dohrn, 1859

Genus *Stroggylocephalus* Flor., 1861

Stroggylocephalus agrestis (Fallen, 1806) (Plate 1, Fig. 1). A large dark brown species taken only in the early spring. Lake and Tippecanoe counties. April 23-27.[2]

Genus *Acucephalus* Germar, 1833

Acucephalus albifrons (Linnaeus, 1758) (Plate 1, Figs. 5, 6). Fairly common in old meadows where, according to Ball, it feeds on plantain. Grant, Jasper, Kosciusko, Lake and Tippecanoe counties. June 21-July 18.

Genus *Xestocephalus* Van Duzee, 1892

Xestocephalus tessellatus Van Duzee, 1894 (Plate 1, Fig. 4).—One specimen collected at Lafayette in 1934 (no other date) furnishes the only record.

Xestocephalus pulicarius Van Duzee, 1894.—Tippecanoe and Wayne counties. July 5-Oct. 9.

Xestocephalus similis Peters, 1933.—Noble and Tippecanoe counties. August 23-Sept. 22.

Xestocephalus brunneus Van Duzee, 1907.—The most common species of the genus in Indiana according to collection records. Taken from willow and black locust. Porter, Pulaski, Putnam, Tippecanoe, Wabash and Warren counties. May 30-July 8.

Xestocephalus superbus (Provancher, 1890) (Plate 1, Fig. 3).—Noble county. Aug. 10.

Genus *Nionia* Ball, 1915

Nionia palmeri (Van Duzee, 1891) (Plate 1, Fig. 9).—Decatur county. Oct. 19.

Tribe JASSINI Dohrn, 1859

Genus *Hecalus* Stal, 1864

Hecalus lineatus (Uhler, 1877) (Plate 1, Figs. 2, 7).—This species shows striking sexual dimorphism, the female being the largest Indiana leafhopper of the subfamily. It feeds upon *Spartina michauxiana*, the tall slough grass. Huntington, Jasper, Lake and Pulaski counties. July 2-19.

Genus *Parabolocratus* Fieber, 1866

**Parabolocratus major* Osborn, 1915. (Plate 1, Fig. 8).—Harrison, Lake, Noble and Tippecanoe counties. May 12-Sept. 6.

Parabolocratus flavidus Signoret, 1879.—Collected from willow. Lawrence and Harrison counties. July 20-29.

Genus *Dorydiella* Baker, 1897

Dorydiella floridana Baker, 1897 (Plate 2, Fig. 1).—Taken in low lands bordering ponds. It feeds probably on rushes. Lake county. Sept. 6.

Genus *Mesamia* Ball, 1907

Mesamia nigridorsum Ball, 1907 (Plate 2, Fig. 2).—A conspicuously marked leaf-

2 The dates indicate the earliest and latest seasonal record available.

hopper found on Helianthus. Kosciusko, Lake and Tippecanoe counties. May 29-Oct. 7.

Genus *Bandara* Ball, 1931

Bandara johnsoni (Van Duzee, 1894).—Crawford, Harrison, Porter, Tippecanoe, and Warren counties. June 9-August 30.

Genus *Sanctanus* Ball, 1932

Sanctanus sanctus (Say, 1831).—The writer has seen no specimens of this species but Say described it from Indiana in 1831.

Genus *Scaphoideus* Uhler, 1889

Scaphoideus ochraceous Osborn, 1898.—Carroll and Tippecanoe counties. July 7-July 28.

Scaphoideus productus Osborn, 1900 (Plate 2, Fig. 11).—Jefferson, Lake, Porter, Rush, and Tippecanoe counties. June 29-Oct. 2.

Scaphoideus nigricans Osborn, 1910.—Tippecanoe county. Oct. 9.

Scaphoideus intricatus Uhler, 1889 (Plate 2, Fig. 12).—Lake county. August 26.

**Scaphoideus immistus* (Say, 1831).—An extremely variable species. Described by Say from Indiana specimens. Harrison, Kosciusko, Lake, Lawrence, Ripley, and Tippecanoe counties. June 6-Oct. 15.

Genus *Osbornellus* Ball, 1932

Osbornellus auronitens (Provancher, 1889).—Lake, Lawrence, Noble, Porter, Tippecanoe and Wayne counties. July 15-Oct. 6.

Osbornellus consors (Uhler, 1889).—Taken on oak and willow. Carroll, Harrison, Lawrence, Marion, Morgan, and Tippecanoe counties. June 16-Nov. 7.

Osbornellus unicolor (Osborn, 1900) (Plate II, Fig. 10).—Clark and Lawrence counties. August 1-August 21.

Genus *Platymetopius* Burmeister, 1838

Platymetopius vitellinus (Fitch, 1851).—This species is not reported south of Indiana and seems to be a northern form. Clark, Lake, Lawrence, Porter and Tippecanoe counties. July 1-August 9.

Genus *Japanus* Ball, 1931

Japanus hyalinus (Osborn, 1900) (Plate 2, Fig. 9).—Easily recognized by the transparent tegmina. The food plant seems to be maple exclusively. Harrison, Lawrence, Morgan, St. Joseph, Tippecanoe and Warren counties. June 29-Oct. 20.

Genus *Platymoideus* Ball, 1931

Platymoideus cinereus (Osborn & Ball, 1897). Jaseper county. July 6-18.

**Platymoideus acutus* (Say, 1831).—A very common species. Reported from a number of species of plants. Described by Say from Indiana specimens. Throughout the state. May 30-Oct. 10.

Platymoideus acutus var. *dubius* (Van Duzee, 1910). Tippecanoe county. July 7.

Platymoideus cuprescens (Osborn, 1905) (Plate 1, Fig. 10).—An easily recognized copper colored species. Taken on trailing blackberry. Porter county. June 21.

Genus *Nasutoideus* Ball, 1931

Nasutoideus frontalis (Van Duzee, 1890) (Plate 1, Fig. 11).—A very common species throughout the state. Taken from blackberry and a number of other plants. The blackberry is probably its true food plant. May 18-Nov. 7.

Nasutoideus magdalensis (Provancher, 1889).—This species has been reported as feed-in on blueberry and it has been bred from egg to adult on cranberry. Noble and Starke counties. July 4-25.

Genus *Flexamius* DeLong, 1926

Flexamius areolatus (Ball, 1899) (Plate 1, Fig. 12).—This species has been reported as living on *Eragrostis pectinocea*, the purple lovegrass. Lake county. July 4.

Flexamius inflatus (Osborn and Ball, 1897).—Jasper, Kosciusko, Pulaski, Rush and White Counties. June 9-Sept. 14.

Flexamius pictus (Osborn, 1907).—Reported as occurring on *Aristida oligantha*, the few-flowered triple-awn-grass. Clark and Harrison counties. July 1-August 31.

Genus *Palus* DeLong and Sleesman, 1929

Palus marginatus (DeLong, 1918).—Taken on sedge. Noble County. July 10-25.

Genus *Latulus* DeLong & Sleesman, 1929

Latulus sayi (Fitch, 1851).—Taken abundantly on blue grass. Throughout the state. May 13-Nov. 10.

Latulus misellus (Ball, 1899).—Porter county. June 21.

Genus *Polyamia* DeLong, 1926

Polyamia weedi (Van Duzee, 1892).—This species feeds on various grasses. Boone, Clark, Harrison, Jasper, Morgan, Noble, Tippecanoe and Vigo counties. June 23-Nov. 7.

Polyamia obtectus (Osborn and Ball, 1898).—Jasper county. July 6.

Polyamia apicatus (Osborn, 1900).—Has been reported as feeding on *Panicum huachucae*, the hairy panic grass. Jasper, Kosciusko, Lake and Pulaski counties. June 24-July 5.

Polyamia caperatus (Ball, 1900).—The food plant of this species has been reported as *Andropogon virginicus*. Harrison county. July 1.

**Polyamia inimicus* (Say, 1831) (Plate 2, Fig. 3).—Probably the most common leafhopper occurring in Indiana. It occurs in a great variety of habitats and feeds on many native grasses as well as on wheat, oats, rye, alfalfa, clover, timothy and other crop plants. Reported from Indiana by Van Duzee (3). Throughout the state. April 2-Nov. 18.

Genus *Laevicephalus* DeLong, 1926

Laevicephalus unicoloratus (Gillette & Baker, 1895).—Porter county. July 8.

Laevicephalus sylvestris (Osborn and Ball, 1897).—A common woodland species, reported as feeding on *Danthonia compressa*, the flattened wild-oat-grass. Jasper, Morgan, Noble, Porter and Tippecanoe counties. June 9-Nov. 7.

Laevicephalus acus (Sanders and DeLong, 1920).—Jasper, Morgan, Porter, Pulaski and Tippecanoe counties. June 9-Nov. 7.

Laevicephalus orientalis De Long and Davenport, 1935 (Plate 2, Fig. 4).—Tippecanoe county. June 10-July 1.

Laevicephalus striatus (Linnaeus, 1746).—Collected very commonly. It is one of the most abundant forms to be found in grasslands and is at times a serious pest of cereal and forage crops. Throughout the state. April 29-Nov. 10.

Genus *Amplicephalus* Delong, 1926

**Amplicephalus osborni* (Van Duzee, 1892).—Lake and Tippecanoe counties. July 14-Sept. 6.

Genus *Deltocephalus* Burmeister, 1838

Deltocephalus sonorus Ball, 1900.—In as much as this species has never been reported apparently north of Tennessee this record is of unusual interest. Harrison and Tippecanoe counties. July 6-Sept. 10.

Deltocephalus flavicosta Stål, 1862 (Plate 2, Fig. 5).—Taken throughout the state but more commonly in the southern part. One of the characteristic leafhoppers of hilly pasture lands. June 14-Nov. 7.

Genus *Unerus*, DeLong, 1936

Unerus nigrifrons (Forbes, 1864).—A very common species which is often a serious pest of cereals. Throughout the state. April-Nov. 10.

Genus *Driotura* Osborn and Ball, 1898

Driotura robusta Osborn and Ball, 1898 (Plate 2, Fig. 6).—A meadow species, usually taken on dry upland grasses. Harrison and Pulaski counties. July 2-Sept. 7.

**Driotura gammaroides* (Van Duzee, 1894) (Plate 2, Figs. 7, 8).—Taken on Johnson grass. Bartholomew, Carroll, Delaware, Harrison and Tippecanoe counties. April 22-Oct. 5.

Genus *Exitianus* Ball, 1929

**Exitianus obscurinervis* (Stål, 1858) (Plate 2, Fig. 13).—A very common species throughout the state. March 27-Nov. 18.

Genus *Drylix* Edwards, 1922

Drylix striolus (Fallen, 1806).—Reported from various sedges. Tippecanoe county. June 15-29.

Drylix parallellus (Van Duzee, 1891).—Lake county. July 1.

Drylix truncatus Sleesman, 1929 (Plate 2, Fig. 14).—Lake county. July 1-Sept. 5.

Genus *Euscelis* Brullé, 1832

Euscelis extrusus (Van Duzee, 1893) (Plate 2, Fig. 15).—Clark, Kosciusko, Lake and Warren counties. May 12-July 4.

Genus *Ophiola* Edwards, 1922

Ophiola uhleri (Ball, 1911).—Noble and Porter counties. July 15-August 26.

Ophiola anthracina (Van Duzee, 1894) (Plate 2, Fig. 16).—Reported as occurring on high, dry meadow grasses. Taken quite commonly in Indiana. Harrison, Morgan, Pulaski and Warren counties. June 20-July 9.

Ophiola vara (Ball, 1901).—DeKalb county. July 10.

Ophiola striatula (Fallen, 1826).—Pulaski county. July 2.

Ophiola osborni Ball, 1928.—Collected on blackberry. Harrison, Lake, Porter, Pulaski and Tippecanoe counties. June 21-July 9.

Genus *Commellus* Osborn and Ball, 1902

Comellus comma (Van Duzee, 1892) (Plate III, Fig. 1).—Reported from *Elymus canadensis* and *E. striatus* and collected on sweet clover. Tippecanoe county. June 21-July 4.

Genus *Stirellus* Osborn and Ball, 1902

Stirellus bicolor (Van Duzee, 1892) (Plate III, Fig. 2).—Taken on bluegrass, alfalfa, clover, and willow. It is, however, primarily a grass feeder. Clark, Harrison and Lawrence counties. July 1-Sept. 6.

Stirellus obtutus (Van Duzee, 1892) (Plate 3, Fig. 3).—Taken locally in abundance on bluegrass. Harrison, Johnson and Morgan counties. Oct. 15-Nov. 12.

Genus *Amblysellus* Sleesman, 1929

Amblysellus curtisii (Fitch, 1851) (Plate 3, Fig. 4).—Very common on bluegrass. Hamilton, Kosciusko, Lake, Madison, Miami, Morgan, Noble, Tippecanoe and Vigo counties. June 11-Nov. 1.

Genus *Eutettix* Van Duzee, 1892

**Eutettix pictus* Van Duzee, 1892.—Harrison, Jefferson and Tippecanoe counties. July 5-August 8.

Eutettix southwicki Van Duzee, 1894.—Lake county, Sept. 22.

Genus *Opsius* Fieber, 1866

Opsius stactogalus (Amyot, 1847) (Plate 3, Fig. 5).—An imported species found on tamarax. Lawrence and Tippecanoe counties. August 27-Oct. 20.

Genus *Norvellina* Ball, 1931

**Norvellina seminudus* (Say, 1831) (Plate 3, Fig. 6).—Taken commonly on shrubs throughout the state. May 6-Oct. 16.

Norvellina chenopodium (Osborn, 1923) (Plate 3, Fig. 7).—Fountain, Jasper, Lawrence, Pulaski and Tippecanoe counties. May 20-Oct. 6.

Norvellina pulchellus (Baker, 1896) var. *scaber* (O&B) (Plate 3, Fig. 8). Lake county. July 1.

Genus *Menosoma* Ball, 1931

Menosoma cincta (Osborn and Ball, 1898) (Plate 3, Fig. 10). Bartholomew, Harrison, Lake, Lawrence, Tippecanoe, and Wayne counties. July 23-Oct. 16.

Genus *Phlepsius* Fieber, 1866

Phlepsius irroratus (Say, 1831) (Plate 3, Fig. 13).—One of the most common leafhoppers occurring in Indiana. It may be a decided pest of grain crops under favorable conditions. Feeds on a wide variety of plants. Throughout the state. April 20-Dec. 23.

Phlepsius truncatus Van Duzee, 1892.—Delaware, Fountain, Harrison, Lake, Morgan, and Tippecanoe counties. June 23-Sept. 25.

Phlepsius fuscipennis Van Duzee, 1892.—Lake county. July 1-12.

Phlepsius puscillus Baker, 1898.—Clark county. August 31.

Phlepsius incisus Van Duzee, 1892. Morgan county. July 14.

Plepsius fulvidorsum (Fitch, 1851). Tippecanoe county. July 7.

Phlepsius collitus Ball, 1903.—Harrison, Lake, Lawrence, Jefferson, Noble, and Porter counties. June 5-Sept. 5.

Phlepsius tennessa DeLong, 1916.—Taken on bluegrass. Clark and Tippecanoe counties. July 4-Oct. 4.

Phlepsius nebulosus Van Duzee, 1892.—Harrison, and Lake counties. July 1-30.

Phlepsius slossoni Ball, 1905 (Plate 3, Fig. 14).—This record is quite unusual as this species has heretofore been reported no farther north than North Carolina. Our record is based on a single specimen labeled "Lafayette, Ind., 1934."

Phlepsius solidaginis Walker, 1851.—DeKalb, Lake, Noble, Porter, St. Joseph, and Tippecanoe counties. July 1-Oct. 16.

Genus *Texananus* Ball, 1918

Texananus majestus (Osborn and Ball, 1897).—Lawrence, and Tippecanoe counties. July 16-Oct. 7.

Texananus superbus (Van Duzee, 1892).—Clark county. July 2.

Texanus decorus (Osborn and Ball, 1897).—Bartholomew, Jennings, Lawrence and Tippecanoe counties. July 4-Oct. 15.

Texananus rufusculus Osborn and Lathrop, 1923.—Tippecanoe county. April 24.

Genus *Acinopterus* Van Duzee, 1892

Acinopterus acuminatus Van Duzee, 1892 (Plate 3, Fig. 9.)—Carroll, Clark, Lake,

Lawrence, Montgomery, Morgan, Porter, Tippecanoe and Warren counties. May 5-Oct. 26.

Genus *Idiodonus* Ball, 1936

Idiodonus kennicotti (Uhler, 1863) (Plate 3, Fig. 11).—Clark, Lake, Morgan and Tippecanoe counties. May 7-Oct. 7.

Idiodonus brittoni (Osborn, 1907).—Tippecanoe and Warren counties. April 23-July 7.

Genus *Colladonus* Ball, 1936

**Colladonus clitellarius* (Say, 1831).—A common species frequently taken on willow. Throughout the state. May 24-Nov. 7.

Genus *Doleranus* Ball, 1936

Doleranus perspicillatus (Osborn and Ball, 1897).—Tippecanoe county.

Doleranus longulus (Gillette and Baker, 1895).—Taken quite commonly. One specimen collected Jan. 31, hibernating under dead leaves would seem to show that this species overwinters in the adult stage. Hamilton, Harrison, Kosciusko, Morgan, Tippecanoe, and Warren counties. April 22-Jan. 31.

Genus *Cyperana* DeLong, 1936

Cyperana cyperacea (Osborn, 1898).—Taken on sedges in the northern part of the state. Noble county. June 20-July 25.

Cyperana melanogaster (Provancher, 1872). This species is also a sedge feeder. Lake, Noble, Porter, Rush, and White counties. June 20-Sept. 14.

Cyperana smithi (Van Duzee, 1892).—Lake county. Sept. 5.

Genus *Elymana* DeLong, 1936

Elymana inornata (Van Duzee, 1892).—Carroll, Harrison and Tippecanoe counties. June 11-July 14.

Genus *Graminella* DeLong, 1936

Graminella pallidula (Osborn, 1898).—Tippecanoe county. May 30.

Graminella fitchii (Van Duzee, 1890).—Harrison, Noble, Porter, and Tippecanoe counties. July 20-Oct. 16.

Genus *Chlorotettix* Van Duzee, 1892

Chlorotettix tergatus (Fitch, 1851).—Kosciusko, Lake, Noble, Pulaski, and Tippecanoe counties. July 20-August 26.

Chlorotettix necopinus Van Duzee, 1892.—Lawrence county. June 29.

Chlorotettix spatulatus Osborn and Ball, 1897.—Tippecanoe county. July 7.

Chlorotettix unicolor (Fitch, 1851).—Blackford, Carroll, Clark, Elkhart, Jasper, Kosciusko, Lake, Morgan, Noble, Pulaski, Starke, St. Joseph, and Tippecanoe counties. June 28-Sept. 5.

Chlorotettix viridius Van Duzee, 1892.—Fountain, Harrison, Jasper, Jennings, Lawrence, Morgan, and Tippecanoe counties. June 16-Nov. 7.

Chlorotettix lusorius Osborn and Ball, 1897.—Harrison and Tippecanoe counties. July 3-Oct. 7.

Chlorotettix vividus Crumb, 1915.—Lake, Noble, and Tippecanoe counties. July 1-Oct. 1.

Chlorotettix galbanatus Van Duzee, 1892.—A common species. Throughout the state. June 26-Sept. 29.

Chlorotettix balli Osborn, 1898.—Harrison, Lake, Noble and St. Joseph counties. July 1-July 28.

Chlorotettix tunicatus Ball, 1900.—Harrison and Jasper counties. June 18-July 4.

Chlorotettix nudatus Ball, 1900.—Morgan county. July 13.

Genus *Jassus* Fabricius, 1803

Jassus olitorius Say, 1831 (Plate 3, Fig. 16).—Bartholomew, Boone, Clark, Hamilton, Harrison, Jefferson, Kosciusko, LaGrange, Lawrence, Porter and Tippecanoe counties. July 12-Nov. 20.

Genus *Neocoelidia* Gillette and Baker, 1895

Neocoelidia tumidifrons Gillette and Baker, 1895.—This species probably feeds on sedge. Harrison and Noble counties. July 10-August 8.

Genus *Davisonia* Dorst, 1937

Davisonia major (Dorst, 1931).—DeKalb, Harrison and Tippecanoe counties. June 25-July 13.

Genus *Macrosteles* Fieber, 1866

Macrosteles variatus (Fallen, 1806).—Porter and Tippecanoe counties. August 9-Sept. 8.

Macrosteles lepidus (Van Duzee, 1894).—Kosciusko, Noble, Porter and Tippecanoe counties. May 6-August 23.

Macrosteles divisus (Uhler, 1877).—A very common and widely distributed species. Throughout the state. May 13-Nov. 10.

Genus *Balclutha* Kirkaldy, 1900

Balclutha abdominalis (Van Duzee, 1892).—Noble, Tippecanoe and Warren counties. May 15-Nov. 10.

**Balclutha impicta* Van Duzee, 1892.—Reported from Indiana by Davidson and DeLong (1).

Genus *Nesosteles*, Kirkaldy, 1906

Nesosteles neglectus (DeLong and Davidson, 1933).—Throughout the state. May 13-Nov. 7.

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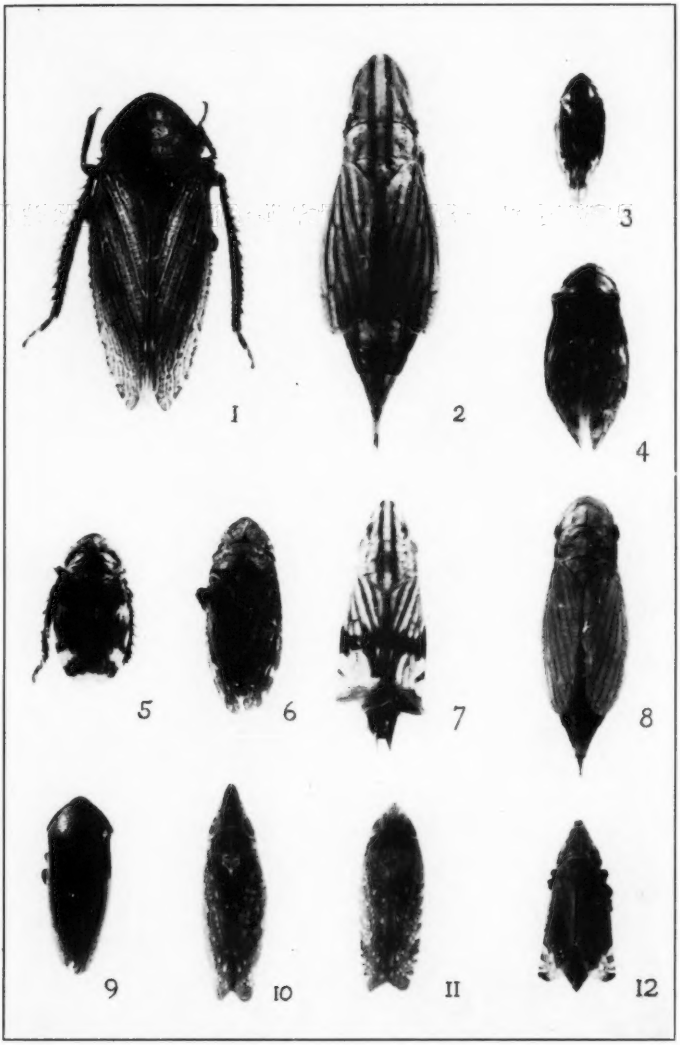

PLATE 1.—(1) *Stroggylocephalus agrestis* (Fallen). (2) *Hecalus lineatus* (Uhler), female. (3) *Xestocephalus superbus* (Provancher). (4) *Xestocephalus tessellatus* Van Duzee. (5) *Acucephalus albifrons* (Linn.), male. (6) *Acucephalus albifrons* (Linn.), female. (7) *Hecalus lineatus* (Uhler), male. (8) *Parabolocratus major* Osborn. (9) *Nionia palmeri* (Van Duzee). (10) *Platymoideus cuprescens* (Osborn). (11) *Nasutoideus frontalis* (Van Duzee). (12) *Flexamius areolatus* (Ball).

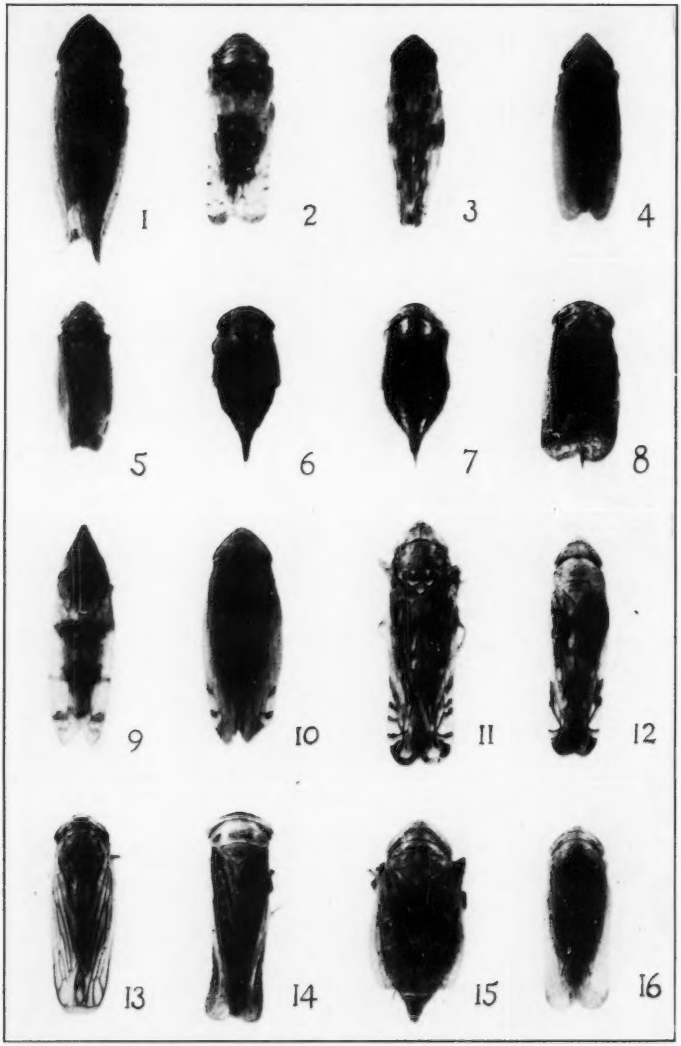

PLATE 2.—(1) *Dorydiella floridana* Baker. (2) *Mesamia nigridorsum* Ball. (3) *Polyamia inimicus* (Say). (4) *Laevicephalus orientalis* (D. & D.). (5) *Deltocephalus flavicostus* (Stål). (6) *Driotura robusta* Ball. (7) *Driotura gammaroides* (Van Duzee), short-winged form. (8) *Driotura gammaroides* (Van Duzee), long-winged form. (9) *Japananus hyalinus* (Osborn). (10) *Osbornellus unicolor* (Osborn). (11) *Scaphoideus productus* Osborn. (12) *Scaphoideus intricatus* Uhler. (13) *Exitianus obscurinervis* (Stål). (14) *Drylix truncatus* Sleesman. (15) *Euscelis extrusus* (Van Duzee). (16) *Ophiola anthracina* (Van Duzee).

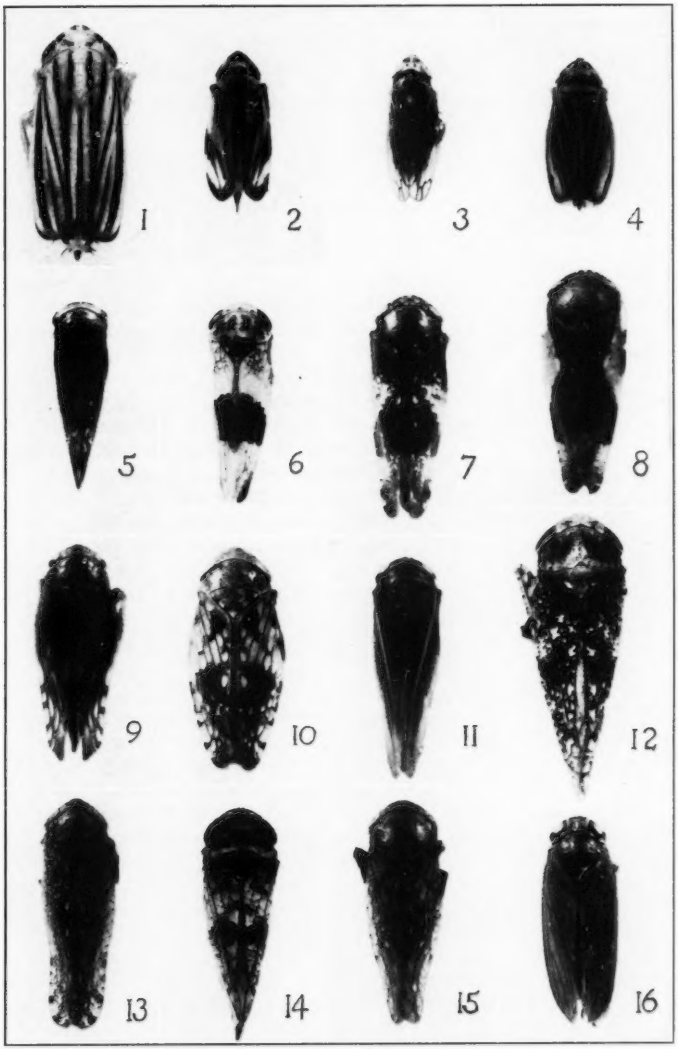

PLATE 3.—(1) *Commellus comma* Van Duzee. (2) *Stirellus bicolor* (Van Duzee). (3) *Stirellus obtutus* (Van Duzee). (4) *Amblysellus curtisii* (Fitch). (5) *Opsius stactogalus* (Amyot). (6) *Norvellina seminuda* (Say). (7) *Norvellina chenopodii* (Osborn). (8) *Norvellina pulchella* (Baker) var. scaber (Osborn and Ball). (9) *Acinopterus acuminatus* Van Duzee. (10) *Menosoma cincta* (Osborn and Ball). (11) *Idiodonus kennicotti* (Uhler). (12) *Phlepsius collitus* Ball (13) *Phlepsius irroratus* (Say). (14) *Phlepsius slossoni* Ball. (15) *Phlepsius fuscipennis* Van Duzee (16) *Jassus olitorius* Say.

The Breeding Habits of the Silvery Minnow, Hybognathus regius Girard

Edward C. Raney

Little has been recorded concerning the breeding habits of the Silvery Minnow, *Hybognathus regius* Girard. Bean (1903, p. 118) wrote that it spawns in early spring. Wright and Allen (1913, p. 4) have given April 25 to June as the breeding time and quiet water and riffles as the breeding place. Adams and Hankinson (1928, p. 366) concluded that the eggs were probably laid in the spring after finding schools of young about an inch long in July in Oneida Lake, New York.

Studies carried on for the past several years at the south end of Cayuga Lake near Ithaca, New York, have shown that the Silvery Minnow is one of the earliest of our northeastern cyprinids to spawn. The more pertinent notes on breeding behavior are here recorded. Considerable additional data on the economics of this species based on studies still in progress at the Cornell Experimental Hatchery will be reported in a subsequent paper. However, it should be mentioned at this time that it shows considerable promise as a bait and forage fish which may be easily raised in small ponds. In the Finger Lakes Region of New York the males and, to a lesser extent, the females are a very important spring bait minnow for the Pike, *Esox lucius*, and the Pickerel, *Esox niger*.

Migration

Near the middle of March large numbers of the Silvery Minnow migrate into the small coves (Fig. 1.) which lead off from the sluggish portion of lower Fall Creek just before it enters Cayuga Lake near Ithaca. Although an occasional specimen may move in over the spawning grounds in October and November, no large schools have been seen in the fall. The spring migration reaches its climax during the last week in April. Some idea of the immense numbers which may occur was obtained by observing the activities of commercial bait fishermen. On April 24, 1938, by hauling a 50 foot bag seine through a small cove 75 feet wide and 200 feet long, they captured approximately 4,000 adults. Repeated hauls on the same and succeeding days were rewarded with slightly smaller catches. Although the numbers dwindled gradually after the middle of May the Silvery Minnow was still the most abundant species of minnow of bait fish size taken throughout May. It appears that the collection of these unspawned fish in such great numbers over a period of years is rather poor conservation practice. The great spring concentration of this species has also been noted by Smith (1907, p. 86) who

1 Taken by the New York State Biological Survey.

observes that in April, 1902, in Pasquotank River, this species was numerous "probably surpassing in abundance any other fish of the family."

The males come into the coves earlier and stay later than the females. There are at all times more males on the spawning grounds. Of 319 unselected adults taken over the breeding areas at various times during late April and May, 1938, there were 61 females and 258 males. It is likely that the females may move out of the area after spawning while individual males may stay for longer periods. Evidence that males are not more abundant at all seasons is indicated by a fairly large collection[1] taken September 1, 1931 in Lake Ontario at Montario which contained 36 males and 52 females.

By June 1 only males were to be found in the cove where spawning was observed. After the middle of June adults were rarely taken and had apparently gone out into the lake.

The common associates in the quiet coves where spawning occurs are *Catostomus commersonnii commersonnii, Cyprinus carpio, Notropis bifrenatus, Notropis heterolepis heterolepis, Notemigonus crysoleucas crysoleucas, Hyborhynchus notatus, Ameiurus nebulosus nebulosus, Schilbeodes gyrinus, Esox niger, Esox lucius, Boleosoma nigrum olmstedi, Micropterus dolomieu, Huro*

Fig. 1. Cove off Fall Creek near Cayuga Lake, Ithaca, New York. Spawning was observed April 26-28, 1938 near the border of the grass shown in the foreground.

salmoides and *Lepomis gibbosus*. Less often *Pomolobus pseudoharengus*, *Notropis hudsonius hudsonius* and *Notropis spilopterus* are found on the spawning grounds. It appears that the juvenile *Hybognathus* might serve as an important forage fish for both the juvenile Pickerel, *Esox niger*, and Pike, *Esox lucius*. These two predacious species have just spawned several weeks to a month before.

Sexual Dimorphism

At the spawning season adult males and females differ in coloration, location and abundance of breeding tubercles and size. The males are light yellow along the sides, from the eye posteriorly over the operculum to the base of the tail. The mid-line of the belly is silvery. All the fins of the male are a faint yellow, the color being least pronounced in the dorsal. The females are silvery as are the males other than during the spawning period. The males are much darker than the females, especially when viewed from above. The differences in coloration are so striking that the local bait fishermen believe they are separate species and designate them by different common names.

The breeding males have small light colored breeding tubercles scattered densely over the top and sides of the head, on the chin, cheeks, opercles and on the apical edge of the scales, of the back and sides. The tubercles are more abundant on the more anterior scales. Both sides of all the fins of the males have tubercles but they are better developed on the upper sides of the pectoral and ventral fins. The ripe females have a few minute tubercles scattered over the top of the head and on the pectoral and ventral fins.

The females attain a larger size than the males. This character, as well as the swollen abdomen of the female, was useful in distinguishing the sexes during spawning. The largest male examined was 83 mm. standard length; the largest female was 100 mm. Of 61 adult females taken during late April and May 1938, 19 or 31 per cent were longer than the largest male. While Fowler (1909, p. 522) reports that this species "is said to reach 9 inches in length" Adams and Hankinson (1928, p. 364) took "none more than four inches" in Oneida Lake. Smith (1907, p. 86) gives the maximum length as 6 to 7 inches, with an average length of 4 inches. Among several thousand specimens examined from New York State the largest was 120 mm. (4.8 inches) in total length.

Spawning

Unlike any of our other northeastern minnows whose breeding habits are known, the Silvery Minnow lays its non-adhesive eggs on the bottom ooze in the quiet water of coves. (Fig. 1) The bottom is partly covered with the decaying vegetable material of the previous year as leaves, small branches and grass. A few weeks later these same coves are choked with vegetation as the mat forming water clover, *Marsilia quadrifolia*, several species of pond weed, *Potamogeton*, and spatterdock, *Nymphozanthus advena*, and are utilized by spawning Carp, *Cyprinus carpio;* the Golden Shiner, *Notemigonus crysoleucas crysoleucas;* the Common Bullhead, *Ameiurus nebulosus nebulosus;* the Tad-

pole Cat, *Schilbeodes gyrinus* and the Large-mouthed Black Bass, *Huro salmoides*. However, at the spawning time of the Silvery Minnow only the stalks of the water clover are to be seen in the deeper areas. Close to and on shore occurs an abundance of reed canary grass, *Phalaris arundinacea*. This grass gives considerable shelter to which these minnows retire when frightened. Here also most spawning takes place usually in water up to one foot in depth.

The following spawning observations were made April 26, 27 and 28, 1938. During the day the air varied from 20° C. to 28° C.; the water from 13° C. to 20.5° C. A change in weather resulting in a sudden drop in water temperature brought a temporary halt to spawning on April 30. No other spawning activity was observed but it undoubtedly continued at least to the middle of May as ripe males and females were taken together several times up until this date.

Spawning activities started in the morning about 10 a.m. and continued until about 4 p.m. Activity reached its greatest height from 12 noon to 2 p.m. No spawning takes place at night. After dark the Silvery Minnows may be seen lying quietly at the bottom. They are always more concentrated in the newly sprouted grass near the shore.

As one approached the breeding grounds the *Hybognathus* would quickly take shelter either under a nearby log or in the grass along shore. After a short time however they returned to their former activities and would not scare except when quick movements were made. Spawning groups were studied often at a distance of from 2 to 3 feet from my observation post at the side of the cove. At one time a group spawned within a few inches of my foot.

At the spawning time the general setup is quite similar throughout the length of the cove which is several hundred yards long but only 10 to 20 feet wide. Many females may be seen lying quietly or moving slowly about in the central waters where the depth varies from 1 to 2.5 feet. The males are very active but are usually confined to the grassy borders where the actual spawning takes place. However, it was found that successful spawning may take place where there is no vegetation in small ponds at the Cornell Experimental Hatchery. No territory is held and no fighting was observed among the males. Individuals of both sexes were occasionally seen coming to the surface to gulp air.

When ready to spawn a female will move slowly toward the shallow water at the side of the cove. From one to ten males will move at once toward her. The first two to get to her swim slightly underneath on opposite sides and nose her slightly in the region in front of and about the anus. The other males will attempt to squeeze out the two males which first reached her. If they fail to replace the lower males they swim along close to the female's back and sides. The female followed by her retinue of males may at times move quickly in a curved path which usually ends in the center of the cove among the rest of the non-active females. When pursued in this manner a female would often jump out of the water a few inches and travel as much as three feet while in the air. Usually, however, she continues toward the grassy area and spawning occurs.

Breeding is usually accomplished with a male close on either side of a female, near the base of newly sprouted grass in from 2 to 6 inches of water. The eggs are apparently laid as the three vibrate rapidly for a second or two. The breeding vibration although momentary is violent enough to disturb the bottom ooze making the water slightly turbid. When spawning occurs quite close to shore the grass could be seen waving considerably. At times one male appeared to spawn by crowding a female against a clump of vegetation. On other occasions a single female would be accompanied by from 4 to 10 males when spawning took place. However, it appears that only the two males close along side the female are effective. Because of the ooze which is stirred up it was impossible to see details at the moment of spawning.

After spawning the female returns to the deeper waters in the center of the cove. The males again take up their movements near the shore looking for other females. Upon a number of occasions a male would almost immediately spawn again with a different female. It was not determined how soon a female would spawn again nor how many eggs were laid at one spawning although the number is likely quite small.

Some males will take food during spawning activities but the alimentary tracts of females seldom contained anything. The food consists largely of the microscopic material which is found in the bottom ooze. Various diatoms as well as other types of algae appear to be the most voluminous item in the diet. They are remarkably well adapted to digest this microscopic plant food as they possess very long coiled intestines.

Eggs and Young

Just after several spawning acts eggs were observed and recovered. They were scattered over the decaying vegetation and ooze on the bottom. Some eggs may be buried under a few millimeters of ooze. The majority of the eggs were non-adhesive at this time although in a number of cases eggs were observed attached to bits of bottom debris. Perhaps the eggs are adhesive when freshly laid but lose this adhesiveness when water hardened although this did not appear to be the case in a few females which were stripped.

The freshly laid eggs were slightly milky in color and were one mm. in diameter. An attempt to determine the incubation period was made by collecting eggs from the bottom, just after a spawning group had left the spot, and placing them in a small submerged screen box. The eggs hatched in from six to seven days. The water temperature during the day varied from 13.3° to 20.5° C. during this period. Although it appeared several times as if male *Hybognathus* were eating their own eggs this observation is unconfirmed by stomach analysis. No other species were seen feeding upon the eggs.

The number of eggs laid depends upon the size of the fish. There were 6600 developed eggs in the ovaries of large females, 90 mm. in standard length. Females from 68 to 70 mm. had 3000 eggs while those of 60 mm. standard length had 2000. The eggs of ripe fish are about equally developed.

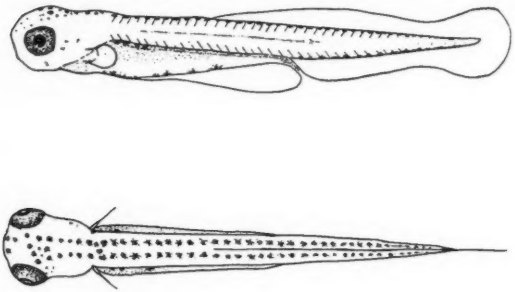

Fig. 2. Newly hatched larva, 5.7 mm. in total length, taken on May 2, 1938 in a cove off Lower Fall Creek near Ithaca, New York.

The eggs are matured during the late fall. A large female taken in the Hudson River the last week in November was considerably swollen with well developed eggs.

Newly hatched larvae (Fig. 2) were recovered on May 2. They averaged 5.5 mm. in standard length, 6 mm. in total length. The characters of the larger larvae are portrayed in Fig. 3.

The larvae remain for a time near the bottom but as the yolk sac is used up they rise and may be found singly in the surface layer. Approximately two weeks after hatching they may be seen in small schools near shore usually among the emergent vegetation. The individuals in a school vary considerably in size even at this time and this, also, is indicative of an extended spawning

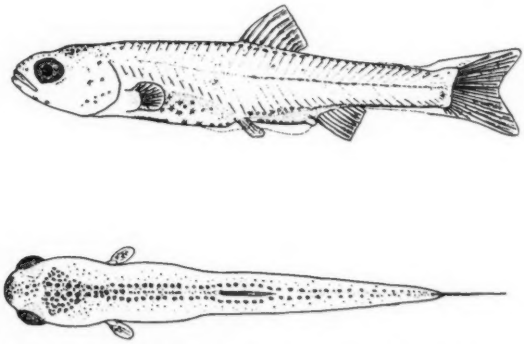

Fig. 3. Larva 12 mm. in standard length, 14 mm. in total length, taken June 4, 1938 from Pond E at the Cornell Experimental Hatchery, Ithaca, New York.

period. Still later small schools may combine to form large groups of several hundreds of individuals which occasionally may be seen at the surface but which more often feed on the bottom ooze as do the juveniles and adults.

Juvenile *Hybognathus* taken July 1 from the lagoon where spawning had been observed were almost an inch in total length, 20 mm. in standard length. By July 15 they were about 1.5 inches in total length, 30 mm. in standard length. At this time a number of young had found their way to the lake shore where they were observed in shallow water. On August 5 the total length was very close to 2 inches, the standard length 40 mm. Some females apparently reach maturity and spawn when a year old and but 50 to 55 mm. in standard length. The slower growing males probably do not spawn until they are two years old.

The drawings of the larvae shown in figures 2 and 3 were drawn from preserved specimens by Mr. Dwight A. Webster.

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Some Effects of Fresh Water on the Fauna of a Marine Harbor

G. E. MacGinitie

During the first week in March, 1938, Southern California was visited by an unusually severe storm. The rainfall accompanying this storm was of sufficient magnitude to cause floods over the greater part of Southern California, with an attendant loss of life and property. Although at present the Santa Ana River empties directly into the ocean, it did in times past use the entrance of Newport Bay as an outlet; and on March 3, 1938, the Santa Ana River broke through one of its levees and a portion of the discharge again found its way through the bay and out the entrance. The stream running into the bay from the break in the levee at the river was 1,000 feet or more wide, had an average depth of a little over one foot, and a velocity of about 2 feet per second, or considerably over 1 mile per hour. This break in the levee occurred at about 3 o'clock in the morning, and it ran about 4 hours before it was finally brought under control.

This amount of water, in conjunction with the run-off from the surrounding hills, supplied a quantity of fresh water which markedly affected the animal life of the bay, and it is the purpose of this paper to summarize some of the effects noted.

It is a well-known fact that fresh water floats on top of salt water for a considerable time if surface disturbance is at a minimum, as it is in Newport Harbor, and that the line between the fresh water and the underlying salt water is often very sharp. The inflow of fresh water into the bay from this storm came at a period of neap tides. The extreme between tides on March 3 was only 4.9 feet, and continued to drop off until, on March 5, the difference was only 3.9 feet, when it again became greater. This allowed the fresh water floating in the bay to remain more or less static for several days.

By taking measurements from the bottoms of boats which were hauled in for cleaning and repair after this flood, it was possible to determine the exact depth to which the fresh water extended, and the most interesting part of the investigation was the determination of this line of demarcation between the fresh water and the underlying ocean water. In the yacht anchorage near Bay Island, which is approximately 2 miles from the entrance of the bay, the animals were killed to a depth of 6 feet 9 inches, and the line of lethal effect of the fresh water was so marked that a boat bottom would be quite clean from this depth up, and well laden with undisturbed marine life from that depth down.

It should be noted here that anchored vessels, from which these readings were obtained, rise and fall with the tide, so that the extent to which fresh water affected the animals on stationary objects, such as pilings, would be 6 feet 9 inches below the lowest tide during the time that the fresh water remained in the bay. Since those marine animals to which fresh water is lethal are, with few exceptions, killed within a few minutes by fresh water, the depth to which the animals would be killed on pilings would be 6 feet 9 inches below the low water mark of 0.4 foot on March 3 at approximately one o'clock (in other words, about 6 feet, 4 inches). By actual measurement at some of the yach basins, it was found that the depth to which the animals were killed actually coincided with the expected effects. Since the extremes between high and low tide became less and less for several days, it can also be reasonably deduced that the main effects of the fresh water occurred on March 3.

Near the entrance of the bay on the inside at the beginning of the jetties, the depth to which the fresh water affected the animals was somewhat less, being approximately 5 feet below the low tide mark of 0.4 feet (or 4 feet, 7 inches), and the line of lethal influence of the fresh water was not so sharply marked as it was in the upper bay. Farther out along the jetties where the outside surge, which was greater than that inside, caused a continual movement of the water in and out among the interstices of the rocks, no apparent disaster occurred, though in places many of the more susceptible animals presented a somewhat sickly appearance for a considerable time.

It should also be noted here that there was a certain amount of dilution of the ocean water along shore by the outflow from the Santa Ana River, which at the height of its flood, 1 mile from the beach, was 12.02 feet above mean low water. However, because of the action of the surf, this fresh water was almost at once well mixed with the ocean water, and, though the volume from the Santa Ana River was great, relatively speaking, the volume of the outside ocean was, of course, very much greater. The currents carried the discharge from the mouth of the river along the beach to the south. Along the rocky shore to the south toward Laguna Beach, it was noted that there was some effect from this fresh water dilution, particularly upon the plant growth. Much of the plant growth became paler in color, and a great deal of it was killed outright. Some of this effect may have been due to the very muddy condition of the water, which would exclude the sunlight from the plants. The water along the ocean shore remained muddy for 3 or 4 weeks.

The following table lists the animals under two headings, those which were killed by fresh water and those which were not. Some remarks will be made relative to particular species at the end of the table.

Table Showing Effects of Flood Waters on Certain Marine Animals, March 3, 1938, Newport Bay, California

ANIMALS KILLED BY FRESH WATER	ANIMALS NOT KILLED BY FRESH WATER
Sponges*	Sponges
	Tetilla mutabilis
Coelenterates	Coelenterates
Corymorpha palma	*Bunodactis xanthogrammica*
Obelia longissima	*Cribrina elegantissima*
Renilla köllikeri	*Edwardsiella californica*
Tubularia crocea	*Harenactis attenuata*
	Stylatula gracilis
Bryozoans	Bryozoans
Bugula neritina	
Crisulipora occidentalis	
Haloporella aperta	
Membranipora membranacea	
Scrupocellaria californica	
Scrupocellaria diegensis	
Annelids*	Annelids
	Arenicola cristata
	Clymenella rubrocincta
	Halosydna insignis
	Pista elongata
	Spirorbis marioni
Echinoderms	Echinoderms
Dendraster excenricus var. *elongatus*	*Amphiodia barbarae*
Pisaster ochraceus	
Strongylocentrotus purpuratus	
Crustaceans	Crustaceans
Barnacles	Barnacles
Balanus tintinnabulum californicum	*Balanus glandula*
	Chthalamus fissus
Shrimps	Shrimps
	Callianassa californiensis
	Crangon californiensis
	Upogebia pugettensis
Crabs	Crabs
Emerita analoga	*Petrolisthes eriomerus*
Molluscs	Molluscs
Gastropods	Gastropods
Bullaria gouldiana	*Aletes squamigerus*
Haminoea virescens	*Cerithidea californica*
Tethys californicus	*Crepidula onyx*
	Crucibulum spinosum
	Murex festivus

Pelecypods	Pelecypods
Saxicava arctica	*Chama pellucida*
	Chione succincta
	Chione undatella
	Macoma nasuta
	Mytilus californianus
	Mytilus edulis
	Ostrea lurida
	Pecten circularis
	Sanguinolaria nuttallii
	Tagelus californianus
	Zirphaea gabbi
	Chitons
	Mopalia muscosa
Cephalopods	Cephalopods
Paroctopus bimaculatus	
Enteropneusts	Enteropneusts
	Dolichoglossus pusillus
Tunicates	
Ciona intestinalis	
Styela barnharti	
Amaroucium californicum	
Botrylloides diegense	
Diplosoma macdonaldi	

It will be seen from the foregoing table that a goodly number of the bay animals were not killed by the fresh water. Most of these were able to do one of two things. They were either able to close off the fresh water, as do the barnacles, mussels and limpets, or they were able to withdraw to a safe depth, as do the tubicolous and burrowing forms, such as annelids, the serpent star *Amphiodia barbarae*, the shrimps, clams and balanoglossus. In the first group some of the animals were sufficiently covered at the incoming tide to be able to open when the ocean water predominated. Others, like the mussel and oyster, which has a narrow vertical distribution near or above mean low water, can stand up to more than 50 percent dilution, but, in any event, most of them are able to close for a week or more without any apparent ill effects.

In the second group the tubicolous animals can, by much the same method as those of the first group, exclude the fresh water; and the burrowers living underground need only to withdraw to the deeper portions of their burrows where the substratum is saturated with ocean water, and where it would take a long time, perhaps several weeks, for the sand and mud to become sufficiently diluted with fresh water to kill them. It will also be noted that those animals which do not come under the two groups just mentioned, and, there-

* A few unidentified species of sponges and annelids were killed by the fresh water. The sponges were encrusting forms and the annelids were, for the most part, small free-living members of the group Nereidiformia. Time did not permit a complete check on these animals until it was too late to be sure of exactly what had taken place.

fore, have no protection from the fresh water, such as hydroids, bryozoans, and tunicates, were, for the most part, killed off.

Space does not permit detailed accounts of the effect of the fresh water on each species, but among those animals which were most obviously devastated by the storm were *Ciona intestinalis, Styela barnharti, Bullaria gouldiana,* and *Strongylocentrotus purpuratus.*

Prior to the storm *Ciona intestinalis* and *Styela barnharti* hung in solid masses from the under side of many of the floats and on the pilings in the bay. Following the storm not a single *Ciona* or *Styela* could be found under any of the floats or attached to solid objects on the mud flats where they were exposed by low tide. However, those which were on the bottom of boats or other objects below a depth of 6 feet 9 inches were unharmed, and they were sufficiently numerous to repopulate the floats with *Ciona,* so that within three months following the storm the floats were covered as thickly as before with Cionas, which, although they had not yet reached their maximum size, were, nevertheless, sexually mature.

Bullaria gouldiana, the bubble shell, was killed in such numbers that thousands of them were floating like bubbles on the surface of the water.

Also prior to the flood, the sea urchins *(Strongylocentrotus purpuratus)* were very abundant on those rocks of the jetty which were just below low tide. The flood waters killed these sea urchins, and hundreds of the tests were washed up on the beach or fell to the bottom between the rocks where they were visible at low tides as whitish patches. Even at the lowest tide not a single sea urchin could be seen on the rocks. But, as with the tunicates, those which were deeper escaped, and later many of them migrated up to the higher rocks. Within a month a few were visible, and, through migration and reproduction, they have gradually increased until they are almost as plentiful as ever on the rocks.

Another animal which deserves special mention is *Dendraster excentricus* var. *elongatus* Clark. While this sand dollar occurs in front of the laboratory in numbers sufficiently great to practically cover the bottom, and, while they were subject to the full effect of the fresh water, unlike the sea urchin, they were practically unharmed.

At the time of writing this paper (December, 1938) all animal life has re-established itself, and those animals which were above the dividing line between the fresh and salt water have been repopulated from members which were below this line, a fact which in itself supplies data as to their vertical distribution. Some forms may have re-established themselves from larvae from outside, or from the jetties, though I deem this rather unlikely, except, perhaps, with the hydroids.

Since the intake for the salt water system of the laboratory is below low water mark, we were able, by pumping at the height of the incoming tide, to keep the water supply sufficiently pure that the animals in the laboratory

managed to survive nicely. Even the most susceptible animals, such as *Ciona intestinalis*, were unharmed in the laboratory.

A great many animals of the bay fauna have not been included in this report because it was difficult in certain instances to be sure of the effect of the fresh water, particularly on those animals which are able to migrate, such as certain annelids, octopi, amphioxus, and crabs, to all of which fresh water is decidedly lethal, but which are again present in their usual abundance. The sand crab *Emerita analoga* offers an interesting example of what burrowing may do for an animal. Within the bay, although there were some fatalities, the Emeritas were not killed to any great extent, but on the ocean beach to the south, where there was a greater seepage of fresh water through the beach sand, many more were killed.

On the whole, judging from the present conditions, it may be said that the flood, while it practically wiped out many of the animals to a depth of approximately 4.5 to 6 feet below mean low water, was, in the long run, advantageous, for many of the animals are re-established more abundantly than ever, and the inflow of freshwater, with the accompanying deposition of sediment over the bay, created a condition which is decidedly favorable to the production of food upon which the estuarine animals depend.

As is true of all field investigations of this type, the principle of variation is always evident, for the records of one animal species is no criterion of how others are affected, e.g., compare the sea urchin with the sand dollar. The value of the foregoing information lies in the verification of such general statements as are summarized below.

Summary

1. Practically all marine animals of bays and estuaries are killed by fresh water.

2. Those which have no method of closing out the fresh water, or which do not live in tubes or burrows are quickly killed by it.

3. Those which do have a method of closing out the fresh water or which live in tubes or burrows may more successfully endure a period of dilution by fresh water.

4. Occasional exceptions, such as the oysters and mussels, are able physiologically to adjust themselves to fresh water dilutions, though each to a different degree.

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Relations of the Vegetation and Climatic Types in Nuevo Leon, Mexico[1]

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I. Introduction

The climates of by far the majority of the world's mountainous regions have never been adequately determined. Lack of data in these usually sparsely populated areas has been the principal cause of this deficiency. The dependence of plants upon climatic conditions has been satisfactorily studied and demonstrated by botanists who had insufficient interest in climate as such to engage themselves in the task of using this dependence as a key to climatic classification. Similarly, the relationship has been recognized by meteorologists but not applied because of the natural tendency of workers in specific fields to rely solely on the type of data in which lie their primary interests. By using the geographic method to determine the relationships of vegetation to climate, it is proposed to map the climatic types and describe the vegetation types occurring in the mountainous state of Nuevo Leon, Mexico. This method was discussed in an earlier paper (Muller, 35). The present study is based upon three seasons of field work in Nuevo Leon (1933, 1934, and 1935) supplemented by two seasons in the Chisos Mountains in Western Texas (1931 and 1932) and one in Coahuila (1936). (See Pl. 5.)

The author wishes to express sincere appreciation of the aid rendered to this study by Dr. A. G. Vestal under whom the problem was done and to Dr. J. L. Page whose generous criticism of the meteorological treatment eliminated many errors. Thanks are especially due Professor Alfred Rehder, through whom the financial aid of the Arnold Arboretum was secured for the summer of 1934. Prof. Rehder, Dr. J. M. Greenman of the Missouri Botanical Garden, and Prof. H. H. Bartlett of the University of Michigan are due thanks for financial support during 1935. Prof. Rehder, the staffs of the Arnold Arboretum and the Gray Herbarium, and Dr. Paul C. Standley of the Field Museum kindly identified the collections. To Prof. Isaac Ochoterena, Director of the Instituto de Biología, Mexico, D. F., Mexico, the author is especially thankful for authority to collect and study in Mexico. To the staff of the American Consulate in Monterrey, to Sr. Daniel Hibler, and to many other individuals whose kind advice and hospitality aided in this work the author acknowledges indebtedness.

II. Effects of Climate on Plant Distribution

The relations of plant distribution and growth to climatic conditions have been studied under various circumstances, but in mountainous areas where, by instrumentation, profound fluctuations may be demonstrated to take place in the space of a very short distance, these studies have yielded the richest returns. Shreve (61) reviewed the effects of altitude on plant growth. He listed insolation, temperature, rainfall, humidity, and evaporation as the principal factors affecting plant growth which vary with altitude and exposure. In studying the relations of native vegetation and climate to agriculture in Colorado Robbins (44) used the distribution of native vegetation to supplement meteorological records where those were scattered.

a. Temperature

Temperature has been much discussed as an influence in the distribution of vegetation (and fauna). Merriam (30, 31) regarded temperature as a complete control of distribution and showed a rough conformity of temperature zones to the distribution of plants and animals. Hall and Grinnell (16) wrote strongly in favor of Merriam's views, but they did not agree with him on the values of the temperatures he designated as limiting the various zones. Shelford (53) and Kendeigh (24), although they did not deny the powerful influence of temperature on biotic distribution, criticized Merriam's suggestion that temperature alone is responsible as well as his method of computing its effect.

Merriam regarded the upper (altitudinal) or northern (latitudinal) limit of distribution of an organism as coinciding with the incidence of the minimum sum of temperature required by that organism during the growing season, as expressed "by the sum of the positive temperatures for the entire season of growth and reproduction." The lower or southern limit he determined by measuring the incidence of maximum temperature tolerated by the organism which he regarded as equal to "the mean temperature of a brief period during the hottest part of the year."

That temperature is in many cases highly effective in limiting the upward or northward extension of certain plants is clearly shown by Shreve (54, 55, 58, 59). He showed, for instance, that where temperature inversions are common, such as in valleys or canyons, it is usually true that desert species will be absent from the floor and lower slopes, where the cold air accumulates, only to reappear on the higher slopes out of range of the cold air. Pearson (38, 39) established a correlation between the distribution of forest types in Arizona and New Mexico and varying lengths of the growing season. He concluded that temperature is effective in limiting the upward extension of tree species.

Bates (1) considered the downward or southward extension of species to be limited by high temperatures. The same view was expressed by Hoffman (19) who stated that the southward extension of northern (animal) species in Mexico is limited by the hot area south of the transverse range of mountains between Mt. Orizaba and Colima. The geographical observations of Calvert (5) and Gadow (15), however, resulted in the conclusion that "the plateau seems to be a much more effective barrier to southerners than is the descent into the hot lowlands to the northern creatures."

b. Rainfall

Rainfall has been credited with profound influence on biotic distribution. Soil moisture, the value of which is one of the most essential conditions for various types of plant growth, was shown by Shreve (56) to be distinctly correlated with significant rainfalls. Of course, variation in soil type has a great effect on the efficiency of a rainfall in causing soil moisture, but under uniform soil conditions rainfall is the determining factor. On the basis of

this relationship between rainfall and soil moisture and the dependence of plant growth upon soil moisture, various workers have shown the relationship of plant distribution to rainfall. Raunkiaer (reviewed by Fuller and Bakke, 14) classified life forms of plants on the basis of sizes of leaves and correlated these growth forms with habitats of various degrees of humidity, thereby placing on a relatively quantitative basis the old concept of degrees of xerophytism and mesophytism in plants. Russell (46) credited periods of extremely low rainfall with greater influence than the means from which they deviate.

McDougall (29) divided the North American continent into moisture belts computed from rainfall and temperature data which, like Merriams zones, coincide roughly with the vegetation regions.

Although Bates (l.c.) saw in high temperatures the control of downward extension of vegetation types in mountainous areas, Pearson (39) determined by transplantation with irrigation that atmospheric temperatures do not limit downward extension. He gave no indication, however, of recognizing the controlling influence of temperature upon humidity and evaporating power. Watson (70) agreed with Pearson: "The tendency of the higher zones to creep down the canyons and of the lower zones to creep up the ridges receives much more plausible explanation in connection with the supply of moisture in the two situations, than through the cooling effects of descending currents and the warming effects of ascending ones." This statement is contrary to Shreve's work on cold air drainage. Pearson (38) summed up the dual problem by crediting the limitation of downward extension to lack of moisture and that of upward extension to low temperatures. The upper limit of tree growth, however, is in many cases the result of a combination of decreased temperatures, decreased precipitation at elevations above the level of maximum rainfall, and increase in evaporating power in rare atmospheres. Depth and duration of snow cover, though they are of great influence in mountains of middle latitudes, probably are of little significance in Nuevo Leon.

Jefferson (21) in reviewing similar problems concluded that "the problem of availability of rainfall for plant growth is too complicated to be solved by using the quotient of rainfall and temperature." He would make amount of wind, prevalence of clear sky, slope of ground, and permeability of the soil prerequisite to such determinations. This view was also expressed by Rübel (45) who with Clements (6) recognized the habitat of an organism as a complex of many factors and not merely one or two.

III. Climatic Variation in Mountainous Areas

That the climates exhibited by mountainous areas are many and varied was effectively summed up by Shreve (57): "Those who have only a textbook acquaintance with climatology, and recall the widely separated isothermal and isoanemic lines of the smoothly constructed maps, may find it difficult to realize that very considerable and very important differences of climate may exist within a stone's throw of each other on account of topography or dissimilar vegetations."

a. Temperature

The atmospheric temperatures of different elevations have been studied in considerable detail. Hann (17, p. 244) gives a textbook summary of the phenomena observed in which the average rates of decrease in temperature with increase in altitude for various latitudes are calculated. The mountains of southern Mexico were credited with a decrease of 0.53° C. for every rise of 100 m. This temperature change is due principally to the adiabatic cooling of air by expansion as one proceeds up an altitudinal gradient. Hann further lists the factors which influence variations in this rate: 1) season (warm months favor a more rapid rate), 2) dry and rainy sides of mountains (the dry side favors a more rapid rate), 3) state of sky (cloudy skies, especially in winter, accelerate the rate), 4) exposure (equatorial-facing slopes have a more rapid rate than poleward-facing slopes), 5) topography (the more massive the mountain or the more gentle the slope, the less rapid is the rate). Hernandez' work, discussed below, is being used in the present study as the basis of temperature gradient factors for purposes of calculation. Shreve (59) measured this decrease in temperature with increasing altitude in Arizona and very successfully correlated it with the occurrence of vegetation types. Pearson (38, 39) made similar correlations in Arizona and New Mexico and found the frostless season to vary by as much as 84 days between timberline of the peaks and the surrounding desert.

Various maps and classifications of climatic types covering the state of Nuevo Leon have been published. Such studies are of necessity based on meteorological data collected by government observatories. In sparsely populated areas such observatories are widely scattered. That this maximum scarcity of stations coincides usually with the maximum diversity of climatic types is largely responsible for the failure of attempts to designate temperatures of mountainous areas. This particularly has been the case in Nuevo Leon. Calvert (5) constructed a map of mean annual isotherms of Mexico and Central America which figured Nuevo Leon as divided into two parts, the coastal plain and piedmont with a mean annual temperature of 20° to 25° C. and the central plateau with a mean annual temperature of 15° to 20° C., making no provision for the lower temperatures of the much higher altitudes of the Sierra Madre Oriental. Page (36) and Hernandez (18) arrived at similar conclusions concerning the temperatures of this area. The fact that none of these workers had any data from the mountains overtopping the central plateau made it impossible for them to determine the temperatures of those areas, as pointed out in an earlier paper (Muller, 35).

b. Rainfall

That rainfall is vastly influenced by topography is a matter of common knowledge. Hann (1.c., p. 301) and Schimper (51) described an increase in rainfall with increase in altitude up to a variable zone of maximum rainfall beyond which there is a tendency for the rainfall to decrease. Increase in rainfall is due to the rising of air currents as they move over a mountain range

resulting in cooling of the air, condensation of water vapor, and precipitation. In some cases a mountain range of sufficient magnitude may cause an increase to be apparent as much as 100 km. in front of the mountains as a result of the "piling up" of air on the windward side. The factors which influence the degree of topographic control of rainfall cited by Hann are: 1) direction and velocity of prevailing winds, 2) height of the mountain above the plain, 3) abruptness of relief, and 4) proximity of bodies of water to windward. The height of the zone of maximum rainfall is determined by the altitude of the surrounding plain, the relations of dew-point and existing temperatures, and the season of the year. The decrease in rainfall at higher altitudes is caused by depletion of the water vapor by precipitation which, in effect, is equal to lowering the dew-point of the atmosphere.

Pearson (38, 39), Shreve (59), Robbins (44), and Bates (1) all determined an increase in rainfall with increase in altitude in various mountains in the western United States. In some cases these increases amounted to as much as 200 to 300 percent from desert plains to subalpine forest and alpine meadow. Pearson credits the desert in New Mexico and Arizona with a mean annual rainfall of 12 inches or less and the pinyon-juniper zone with 12.5 to 18.5 inches. He records anual precipitations as high as 52 inches in both the subalpine and alpine zones.

Climatologists working in Mexico have recognized the topographic control of precipitation. Lopez (27) and Sanchez (48) discussed the phenomenon. Page (l.c.) used altitude as a factor to supplement observatory data in calculating rainfall of intervening mountain areas. Although this is a distinct advance, it has been shown by the present author (35) that, in the case of the mountains of Nuevo Leon, wind direction and a consequent rainshadow effect make the problem too complicated for explanation by elevation alone. Furthermore, in the same study and in one by Jones and Bellaire (23) it was shown that occasionally the maximum precipitation occurs on the leeward side of a mountain (due, in the case of the Mexican locality, to a high degree of convection on the leeward side).

Evaporation in mountain areas has been shown to increase markedly with altitude. Hann (l.c., p. 286) gave a table illustrating decrease in water vapor in the atmosphere to be much more rapid than decrease in pressure. Evaporation increases at high altitudes, independently of relative humidity, as a result of the greater evaporating power at reduced pressures.

IV. Classifications of Climate

Classifications of the climates of northeastern Mexico (incidental to classifications covering greater areas) were made by Thornthwaite (65) and Sanchez (48). Thornthwaite classified the entire state of Nuevo Leon (coastal plain, piedmont, central plateau, and high mountain peaks as "mesothermal, semi-arid, and [with] deficiency of rainfall at all seasons." Sanchez likewise classified the entire area under one head, that of "clima de estepas" (steppe climate).

So far there has been no satisfactory classification of climatic types in the Sierra Madre of Nuevo Leon. Only the instances cited of the detection of certain climatic elements in higher mountains (without determining their geographical extents) may be looked upon as definite advances toward a more accurate classification. It is the author's belief that classifications based solely on precipitation, temperature, and evaporation data can never be satisfactory for ecological purposes in mountainous areas for two reasons: 1) the data are insufficient and often quite lacking, and 2) the relationship between climate and biological phenomena does not lend itself to solution by mathematical formulae.

Apparently climatologists' interests do not include the minutia of climatic variation with which plant geographers and ecologists are so vitally concerned. It is not intended to criticize the work of the climatologists (with which this author claims no familiarity), but it can not be too emphatically stated that existing climatological classifications are worse than worthless to an ecologist or geographer working in mountainous areas. The key to many problems of distribution lie in the equatorward extension of temperate and subpolar species along meridians of high altitude and relatively cold climates. No hint of the existence of such habitats may be seen in the available classifications of northeastern Mexican climates, because there exist no meteorological observatories in the critical areas in question.

V. The Physiography of Nuevo Leon

Nuevo Leon is situated in the line of the Sierra Madre Oriental so that that range passes through the state from northwest to southeast (see Pl. 6). Since the Sierra Madre marks the eastern edge of the central plateau, that part of Nuevo Leon east of the mountains (the northeast sector) is occupied by coastal plain with an upper limit of 500 m. altitude (save for a few scattered piedmont elements which do not profoundly affect this study). That part of the state lying west of the mountains (the southwest sector) is located on the central plateau which in this area has an altitude ranging usually between 1,500 and 2,000 m.

The relief of the eastern "escarpment" is intensified by the occurrence of mountains (the Sierra Madre) rising far above the level of the plateau. These mountains are composed of a complexly folded anticline. Its constituent folds appear variously in disordered outcrops. The highest point (Cerro Potosí) has an altitude of 3,800 m., and several peaks range between 3,000 and 3,500 m. Thayer (64) made no distinction between the Sierra Madre and the plateau, although the mountainous fringe of the plateau occupies a strip 50 to 100 km. wide and is distinctly different in topograpy from an ordinary escarpment with no elevations higher than the plateau. Thayer pointed out the continuity of Mexican physiographic provinces with those in the United States. He wrote, "We are likely to regard the Mexican provinces as ending abruptly on the north at the International Boundary, . . as a matter of fact, the Mexican physiographic provinces extend well into the United States, the natural northern boundary being in a general way the

Pecos-Rio Grande, the escarpment of the Colorado Plateau, and the southern terminus of the Sierra Nevada Mountains . . . includes . . . Transpecos Highlands, Arizona Highlands, and Colorado Desert." His "Anahuac Desert Plateau" includes the Sierra Madre Oriental and the adjacent central plateau in Nuevo Leon, the states of Coahuila, Chihuahua, Arizona, most of New Mexico, and western Texas. Obviously no part of the Sierra Madre Oriental can correctly be termed a "desert plateau" or any other kind of plateau.

VI. Soil Types in Nuevo Leon

The substrata of the various parts of the state and the soils derived from them are by no means homogeneous. The eastern coastal plain and the central plateau are largely composed of fine, relatively mature soils of alluvial origin. The mountain mass is largely limestone and shale which weather into clay loams of more or less uniform character. There exist two outstanding exceptions. One is the occurrence in at least two locations of an igneous intrusion which is composed of a very hard and resistant lava which weathers very slowly and consequently bears an exceedingly thin soil cover which constitutes the most xeric soil in the mountains. Contiguous limestone slopes bear a deep layer of soil and give a much less xeric effect. The second exception is the occurrence in the lower foothills along the east face of the mountains in southern Nuevo Leon and adjacent Tamaulipas of a shale which weathers into a fine clay. This soil is very impervious to water and consequently bears a much more scant and xeric vegetation than the gravelly foothills.

Within the bounds of the relatively homogeneous limestone and alluvial groups, however, one may distinguish vast differences in soils depending upon depth, texture, nature of the humus layer, etc. In many cases the plant responses to these variations are obvious, but in some cases, particularly those concerning the humus layer, the soil condition is in large part the effect and plant growth the cause. The most profound effects of the soil upon plant growth are those of soil depth, and in attempting to use vegetation types as indicators of climate these factors must be eliminated. Fortunately, such influences are readily recognized and evaluated by comparison of physiographically similar areas.

VII. Records of Nuevo Leon Vegetation

Botanical literature is exceedingly poor in descriptions of the distribution of vegetation in the mountains of northeastern Mexico. In an earlier paper the results of three seasons of field work in Nuevo Leon were very sketchily presented by the author (35) to establish the altitudinal variations in vegetation types. Sanders (50) has published a map of Mexico on which are figured vegetation types. The entire state of Nuevo Leon is represented as "scrub—chiefly mesquite, yucca, agave, cactus." The sources from which the map was made were not given. By far the best map so far seen by the author is that of Merriam (31) giving the distribution of his life zones. Aside from the fact that it is not sufficiently detailed, the chief criticism insofar as Nuevo

Leon is concerned is that his "Transition" and "Boreal" areas are much too extensive and continuous. This is a most odd criticism in view of the fact that other cartographers have invariably gone to the other extreme; Merriam, also, failed to give the sources of his data.

The descriptions by Pringle (40, 41) are the most accurate sources of information encountered. They are particularly good insofar as the shrubby plains of the central plateau and coastal plain are concerned. The little known mountainous areas, however, Pringle touched only at Monterrey (Davis, 11), about Doctor Arroyo in the extreme southern portion of the state, and along the western edge of the mountains in Coahuila. From his descriptions a number of the vegetation and climatic zones distinguished in central Nuevo Leon may be recognized.

VIII. Method of Classifying Vegetation and Climatic Types

Although the range of each plant species is of more or less indicator value in the determination of climatic types, the blind use of such criteria is subject to more error than the somewhat more general method of outlining vegetation types. Species too frequently overstep the limits one sets for them, either because of lack of knowledge of their full ranges in setting such limits or because of local habitat variations which have no general climatic significance. Vegetation types, on the other hand, apparently never reach their full development and exhibit their characteristic physiognomies or growth forms without corresponding climatic conditions. The theory that vegetation types, climatic types, and, to a limited extent, physiographic types combine to form recognizable natural areas is the basis of this method as outlined in a previous paper (Muller, 35). There is nothing new in this concept except its application. Geographer's "natural regions" have long been distinguished on the same basis.

If the distinction of the various types seems arbitrary, it may be explained by the wholly qualitative nature of some of the criteria and the difficulty in expressing phenomena which are nevertheless tangible when perceived in the field. For instance, the occurrence of a forest of *Quercus affinis* Scheidw., *Q. clivicola* Trel. & Mull., *Pinus pseudostrobus* Lindl., and *P. teocote* Cham. & Schl. may indicate quite different habitats and climatic situations, depending upon the physiognomy of the forest and growth forms of the trees of which it is formed. If the forest is dense and the trees tall, straight, slender, and bearing epiphytes (particularly the larger bromeliads), the climate indicated is *cool* and *subhumid*. If the forest is open and the trees low, gnarled, and free of epiphytes (save lichens and perhaps the smaller bromeliads), at low altitudes such a forest would indicate a *mild* and *semi-arid* climate; at high altitudes such a forest indicates a *cool* and *semi-arid* climate. The gradations between two adjacent types must be referred to one or the other. Such gradations are usually few and of limited extent so that areal limitations are readily set, but where wide transition zones occur, reference to one type or another and the fixation of limits may be somewhat arbitrary. In mapping areas solid

lines are employed. Although overlapping, interfingering, etc. of vegetation types are recognized in this region, no attempt has been made to indicate them cartographically because of limitations of scale. (See Pl. 7.)

Obviously the intricacy of the problem of deciding upon the physical and biotic nature of a given area is much too great to allow the use of simple quantitative criteria. Among the criteria which are regarded as too important to be omitted are the following: 1) identity of dominant species, 2) growth forms of dominant and secondary species, 3) agricultural pursuits, 4) altitude, 5) exposure, 6) observed meteorological conditions and opinions offered by natives, 7) observed soil and substratum conditions.

Eight major vegetation types have been distinguished and serve as the basis of seven major climatic types. Minor variations of these vegetation types are designated as assemblages of similar ecologic requirements and climatic indicator values. Some of the assemblages are edaphic and some locally topographic in cause and consequently are regarded as accessory to the various types to which they belong. They are eliminated from the scheme of climatic indicators, because in such cases climatic factors are not responsible for their occurrences.

IX. Vegetation Types

The following is a list of the major vegetation types; they are not meant to represent any definite transect across the mountains.

a. Central plateau desert scrub
b. Eastern coastal plain scrub
c. Piedmont scrub
d. Montane low forest
e. Western montane chaparral
f. Montane mesic forest
g. Subalpine humid forest
h. Alpine meadow and timberline

These vegetation types do not coincide with those of the Rocky Mountains except in a general way. For instance, although there is some very striking similarity between the subalpine forest described here and that of the Rocky Mountains, they must not be considered synonymous.

a. Central Plateau Desert Scrub

This province is a physiographically limited area of desert plants confined to the high plains to the west of the Sierra Madre. It is characterized by an abundance of thorny species forming thickets or open scrub. *Prosopis chilense* (Mol.) Stuntze, *Celtis pallida* Torr., *Mimosa biuncifera* Benth., *Acacia Greggii* Gray, *A. Roemeriana* Scheele, *A. Berlandieri* Benth., *Microrhamnus ericoides* Gray, *Condalia spathulata* Gray, *Koeberlinia spinosa* Zucc., and *Opuntia imbricata* (Haw.) DC. are common constituents of the vegetation. The desert scrub, however, is by no means a homogeneous thicket of these shrubs. Vast areas are occupied by *Larrea divaricata* Cav., others by *Dasylirion texanum* Scheele with *Agave falcata* Engelm. and *Fouquieria splendens* Engelm., and still others reduced to a bare waste spotted with stunted shrubs, composites, etc. The principal characteristics of this area is the wide spacing of the plants. Only in locally less rigorous habitats are thickets and continu-

ous herb carpets formed. Usually far less than half of the ground surface is covered by the vegetation. As one approaches the mountains or climbs a prominent rise on the desert, the first change observed is not one of identity of species but rather an increase in the numbers, density, and size of the same plants. This transition occurs usually at 2,000 m. altitude.[2]

Grasses occur sparsely save in a few localities where *Bouteloua trifida* Thurb. occurs in sufficient numbers to form a dispersed sod amongst the shrubs.

b. Eastern Coastal Plain Scrub

The eastern coastal plain is very similar in vegetation to the desert plateau. The principal difference exhibited are 1) the greater density and luxuriance of shrubs and low trees, 2) the greater abundance of grasses and herbs, 3) lack of such species as *Opuntia imbricata, Larrea divaricata, Dasylirion texanum, Agave falcata, Fouquieria splendens,* and others characteristic of the desert (these occur on the coastal plain only on locally quite xeric areas such as low, bare ridges), and 4) the occurrence in great numbers of such species as *Cordia Boissieri* DC., *Acacia amentacea* DC., *A. Wrightii* Benth., *A. Berlandieri* Benth., *Yucca treculeana* Carr., *Lippia macrostachya* Wats., *Salvia ballotaeflora* Benth., *Leucophyllum minus* Gray, *Forestiera angustifolia* Torr., *Prosopis chilense, Eysenhardtia polystachya* (Ort.) Sarg., and *Opuntia* spp, which usually are found but sparsely in the less xeric situations on the desert.

Thus floristically as well as in growth form, the desert plateau in Nuevo Leon is more similar to the Coahuilan-Chihuahuan Desert of which it is a part than it is to the eastern coastal plain. Similarly, the eastern coastal plain of North Mexico is more closely related to the Rio Grande Valley and the "brush country" of southcentral Texas Texas than to the desert plateau.

Like the plateau, the coastal plain is characterized by a variety of combinations of species to form several kinds of vegetation. In the northern tip of the state the principal vegetation type is characterized by *Prosopis chilense* and *Opuntia* sp. (a flat-stemmed species) forming a savanna on *Bouteloua trifida, Aristida purpurea* Nutt., *Triodia pilosa* (Buckl.) Merr., and *T. texana* (Thurb.) Wats. In the south and central areas of the coastal plain occur shrub thickets of *Prosopis chilense, Acacia amentacea, A. Berlandieri, Yucca australis* (Engelm.) Trel., *Condalia lycioides* (Gray) Weberb., and numerous less important species of *Acacia, Eysenhardtia, Lippia,* etc. In the area between this and the northern tip described above, the monotonous savanna of tall shrubs is broken by low, rocky hills which frequently present a much more xeric appearance than the plain. Occasionally in flat areas there develop broad "alkali spots" which are notable for the lack of shrubby vegetation and the luxuriance of low halophytes. Rivers passing through the area are accompanied by a very mesic riverbank forest of *Carya pecan* (Marsh.) Engler & Graebn., *Taxodium mucronatum* Tenore, *Salix nigra* Marsh., *Ulmus crassifolia* Nutt., *Celtis mississippiensis* Bosc., and *Acer serratum* Pax.

2 All elevations given in this paper save those of meteorological observatories were calculated from topographic maps published in Mexico (12).

The three preceding variants of the coastal plain scrub are outstanding in appearance and readily recognizable, but each is dependent upon some local factor, either edaphic or topographic, and therefore may not be regarded as of climatic importance. The upper limit of this vegetation type is usually about 500 m. altitude.

c. Piedmont Scrub

The more prominent of the hills on the coastal plain and the foothills adjacent to the Sierra Madre bear a vegetation type which differs from that of the coastal plain in the greater luxuriance of the shrubs and the occurrence of nonthorny species not found on the plain. This type may be referred to as piedmont scrub. The nature of the change from plain to piedmont does not lend itself to the ready distinction of the two types, but some very considerable areas of the upland are characterized by a vegetation type extremely different from that of the plains, so that when the extremes are observed, the distinction is easy, and it is only the gradual transition which is difficult to classify. This gradualness is readily correlated with the gentleness of the rise from plain to piedmont.

The greatest extent of piedmont detached from the mountains is found in northcentral Nuevo Leon where some of the hills reach an elevation greater than 1,000 m. Here one encounters, particularly on northeast slopes, low woods of *Quercus fusiformis* Small, *Leucaena glauca* (L.) Benth., *Cordia Boissieri*, and *Acacia Farnesiana* (L.) Willd. mixed with the various shrubs of the plains.

Essentially similar to the piedmont of the northcentral area is the relatively narrow strip of foothills and lower slopes of the Sierra Madre running over half the length of the state and finally merging with the piedmont in the north. Here, however, the close proximity of the mountain mass exerts an influence which floristically is evidenced by the greater number of nonthorny species and ecologically by the greater luxuriance of those species which occur both on the piedmont and in the foothills. As the lower foothills are reached, the first indication of change in vegetation is the greater abundance and size of woody plants. Less bare soil is seen between the plants, and the more nearly continuous thicket grows taller than the shrubs of the plains. This change is in places evidenced ten to twenty miles in front of the mountain range and independently of any foothills.

On the foothills and lower slopes the vegetation is a low wood of *Acacia Farnesiana*, *A. amentacea*, *Agave americana* L., *Quercus fusiformis*, and *Q. Canbyi* Trel. The upper limit of this zone merges gradually into the next higher zone, the eastern montane low forest. The distinction between the two has been set at that line below which the greater area is occupied by foothill shrubs (such as *Acacia*, *Cordia*, *Opuntia*, etc.) and above which the greater area is occupied by low trees (principally oaks).

Extreme fluctuation may be observed in this zone and particularly along its upper limit where exposed ridge tops are quite xeric and shrub-covered, and

alternating waterways and canyon slopes are relatively heavily wooded. This interfingering of types is topographically induced and therefore, for the purposes of this study, must be discounted. As the waterway woodlands become broader and broader with greater altitude, however, their appearance signifies a climatic change. Another variant occurs along the base of the foothills in the south. At the mountain front opposite Linares, Nuevo Leon, and to the south into Tamaulipas as well as in restricted areas on the plain, there occur outcrops of shale which weathers into an exceedingly fine and impervious clay. The imperviousness of this soil results in an extremely xeric condition which, insofar as it differs from that of surrounding areas, is totally edaphic. In this zone extensive areas are covered with *Dioon edule* Lindl. in almost pure stands.

The coastal plain scrub is separated from the piedmont scrub roughly by the 500 m. contour line except in the north where the gentleness of the rise makes the plains vegetation type reach higher up the slope, in some cases even more than 750 m. Above the piedmont zone the vegetation type gradually changes to a montane low forest. The altitude of this change usually is about 750 to 1,000 m., but on exposed spur tops and south exposed slopes the piedmont scrub may persist to 1,500 m., while in protected canyons it often is displaced by montane low forest at altitudes of 600 m. Thus the east face of the mountains is occupied by bands of varying vegetation types which interfinger with one another, there being an alternation for each opposing north and south slope and for each ridge top and arroyo bottom. By arriving at mean elevations at which these various types become predominant, it is purposed to determine climatically significant facts of distribution.

d. Montane Low Forest

The montane low forest consists principally of oaks. *Quercus clivicola* Trel. & Mull., *Q. Canbyi* Trel., *Q. porphyrogenita* Trel., and *Q. fusiformis* Small are the principal species. Of these *Q. fusiformis* and *Q. Canbyi* most often mingle in the lower extremes of their ranges with piedmont shrubs such as *Acacia amentacea, A. Farnesiana,* and *Cordia Boissieri.* In protected situations *Quercus polymorpha* Cham. & Schl. and *Q. rysophylla* Weatherby form abundant constituents of the wood, while *Pinus pseudostrobus* Lindl. locally reaches abundance on both exposed and protected slopes. Where the forest reaches its best development *Carya myristicaeformis* (Michx.) Nutt. and *Juglans mollis* Engelm. cover extensive areas, either mixed with pines and oaks or locally in almost pure stands. In the upper limits of the area *Quercus cupreata* Trel. & Mull. and *Q. monterreyensis* Trel. & Mull. become important species, while *Q. fusiformis* and, to a lesser extent, *Q. Canbyi* are eliminated. Throughout the area, but particularly in those parts dominated by *Q. clivicola, Agave americana* L. is an important shrub. More local in distribution are the almost pure stands of *Quercus Endlichiana* Trel. and mixtures of that species with *Q. clivicola, Q. cupreata, Juglans mollis,* and *Pinus pseudostrobus* near the upper limits of the zone. *Pinus teocote* Cham. & Schl. forms dense forests with *P. pseudostrobus* as this zone merges into the next higher.

As has been indicated, many of the species occur in more than one zone. This is true partly because the zones are set without regard for the presence or absence of species, partly because the range of one species might coincide with parts of the ranges of two mutually exclusive species, and because growth form rather than specific composition has been the criterion on which these zonal distinctions were made.

The montane low forest is characterized in exposed situations by low trees with trunks usually less than a foot in diameter, branches occurring from six to ten feet above the surface of the earth, trunks and branches frequently somewhat gnarled, and crowns rounded. The trees are usually spaced so as to leave some ground area uncovered. Here *Agave americana* thrives. The sparseness of the forest cover is also responsible for the abundance of grasses, of which *Stipa mucronata* HBK., *Aristida purpurea* Nutt., *A. arizonica* Vasey, *Bouteloua bromeoides* (HBK.) Lag., *B. hirsuta* Lag., and *B. filiformis* (Fourn.) Griff. are the most important. Protected areas in this zone and the upper limits of its extent are characterized by a more luxuriant forest of a definitely more mesic aspect. Thus the area included in this type is a complex one showing in general a gradation from the xeric woodland bordering the piedmont scrub in the lower altitudes to a relatively mesic forest at the upper edge of the zone. This uper forest is about equally mixed pine and broadleaf trees spaced closely and forming a dense canopy. The trunks, while still little more than a foot in diameter and not over forty feet in height in the most extreme cases, are straight and unbranched up to about thirty feet in height. The grasses which were so abundant in the lower reaches are reduced to a few sparse shade-tolerant species of which *Piptochaetium fmbriatum* (HBK.) Hitchc. and *Stipa mucronatum* are the most common. *Agave americana* is abundant only in locally open areas, and mesic shrubs such as *Garrya ovata* Benth., *Prunus virens* (Woot. & Standl.) Standl., *P. capuli* Cav., *Decatropis bicolor* (Zucc.) Planch. become evident in the denser wood. The presence of these species and the growth forms they represent indicate the transition into a more mesic forest type. This usually occurs at about 1,500 m. altitude.

e. Montane Mesic Forest

The montane mesic forest incorporates a great many of the woody species of the western montane chaparral and montane low forest zones. This zone is characterized by dense growths of trees with tall, slender trunks. In the lower ranges of this growth form a number of species of the montane low forest, which marks the upper limits of the eastern piedmont scrub, are important constituents of the vegetation. *Quercus clivicola, Q. monterreyensis, Q. cupreata, Q. Canbyi, Q. polymorpha, Carya myristicaeformis, Pinus pseudostrobus,* and *P. teocote* are in this group. The two pine species persist to the upper limits of the zone where, together with *Q. Greggii* Trel., *Q. affinis* Scheidw., *Q. mexicana* Humb. & Bonpl. f. *Bonplandii* Trel., *Q. Endlichiana* Trel., *Pseudotsuga mucronata* (Raf.) Sudw., and locally *Populus tremuloides* Michx., *Taxus globosa* Schlecht., and *Cupressus arizonica* Greene, they form dense forests. Particularly indicative of this zone is the occurrence of *Tillandsia*

Benthamiana Klotsch and *T. Parryi* Baker. *T. recurvata* L. and *T. usneoides* L., while they frequently occur in the mesic forest, are not of indicator value, for they are quite as common in the montane low forest. The first named *Tillandsias* are not found throughout the mesic forest, but where they do occur they may be regarded as strict indicators.

However strict certain species may be in their ecologic requirements, the listing of their names still does not express the full character of the community to which they belong. In the montane mesic forest, as in the other zones, growth is by far the most important criterion of the nature of the vegetation. At the upper limits of the low forest the slender, unbranched, crowded tree trunks adumbrate the development at slightly higher altitudes of the mesic forest. In the mesic forest this type of tree growth is the general rule. The high crowns form so dense a canopy and cast so dense a shade that the development of an understory of shrubs and herbs is restricted to the occurrence of a few shade-tolerant species which occur rather sparsely here and there. *Mahonia gracilis* (Hartw.) Fedde, *Cornus stolonifera* Michx., *Ostrya virginiana* (Mill.) K. Koch var. *glandulosa* (Spach) Sarg., *Viburnum australe* Mart., and *Rhamnus serrata* Willd. are the principal shrubs. Shade-tolerant herbs (and suffruticose herbs) such as *Lobelia Berlandieri* DC., *Campanula rotundifolia* L., *Desmodium* spp., *Erigeron* spp., etc. are scattered in the forest, but in the clearings they develop a growth which is profuse both in numbers of species and of individuals unlike any of the communities of lower altitudes.

Another character of the mesic forest is the development of a deep humus layer. In the low forest such a well developed layer occurs only in densely wooded arroyos; elsewhere the soil is apt to be only thinly covered if at all. In the mesic forest, on the other hand, the occurrence of a thin humus layer is exceptional save in pure pine forests, on exposed ridge tops, or where erosion is rapid. The greater part of the area has a heavy leaf mold from a few inches to a foot or more in thickness.

The moisture conditions in the mesic forest soils seems to be favorable for the growth of herbs throughout the growing season. At any rate, in no instance was there observed a retardation or cessation of growth of herbs during the comparatively drier season of late summer such as characterizes the piedmont and low forest zones. Observation and handling of the soil indicated moistness in the mesic forest throughout three summers.

The montane mesic forest occurs on the east slope between 1,500 and 2,800 m. forming a very large part of the watershed cover. On the west, however, it is frequently restricted to a very narrow range lying between 2,500 and 3,000 m. and may be entirely lacking.

f. Western Montane Chaparral

On the west side of the mountain range the desert plateau scrub gives way to a western montane chaparral in the foothills bordering the mountains, usually at an altitude of about 2,000 m. The transition is a gradual one or quite sudden, depending on the topography. Where the rise in elevation is

gradual the desert scrub becomes first more luxuriant, then is to some degree replaced by nonthorny shrubs, and, in flat areas of deep soil, may give way entirely to grassland. Abrupt changes in topography, on the other hand, result in a sudden change from sparse desert scrub to dense montane shrub or low forest. This is characterized by a growth form strongly suggestive of California chaparral as described by Cooper (7). The genera *Rhus, Ceanothus, Quercus, Cercocarpus, Samuela (Yucca), Arbutus,* and *Arctostaphylos* are abundant constituents which attest to the relationship of this vegetation type to the California chaparral type. Evergreen species are almost everywhere prominent, but a considerable proportion of the species is deciduous. The outstanding difference between this zone and the desert plateau is the small number of thorny shrubs found at the higher altitudes.

The relationship of the western chaparral to the eastern scrub is obvious in the many species common to both and the gradualness with which the two types merge when a break in the mountain range allows them to mingle. The much greater altitude of the western zone induces a noticeably lower temperature which, together with the usually somewhat lesser rainfall on the leeward side and the consequently greater diurnal and annual temperature ranges, probably is responsible for the vegetational differences. None of the coastal plain species which make up such large parts of the piedmont scrub on the east slope ever attain any significance in the western montane chaparral.

This vegetation type includes a greater number of important woody species than any other type in the region. It is an exceedingly heterogeneous group of plant assemblages having in common the following characters: 1) shrub habit, 2) importance of evergreen species, 3) density of plant cover, and 4) an altitudinal range subtended below by central plateau desert scrub and above by montane mesic forest or subalpine humid forest. In presenting the following list of important shrub species it is not meant to imply that in any place will all these species be found assembled in one community. In one area *Quercus flocculenta* may be widely dominant. In another *Pinus cembroides* associated with *Rhus virens* may entirely replace *Quercus.* In yet another *Ceanothus lanuginosa, Arctostaphylos pungens,* and *Quercus cordifolia* are dominant. In the following list are proposed a representative group of dominant and subdominant plants found in the western montane chaparral.

Quercus cordifolia Trel.
Q. saltillensis Trel.
Q. flocculenta C. H. Mull.
Q. Pringlei von Seemen
Q. errans Trel. f. *graciliramis* C. H. Mull.
Q. clivicola f. *dentata* Trel. &. Mull.
Q. porphyrogenita Trel. f. *macropetiolata* C. H. Mull.
Ceanothus lanuginosus (Jones) Rose
Ceanothus ferox Standl.
Cercocarpus majodensis Schneid.
C. eximius (C. Schn.) Rydb.
Rhus microphylla Engelm.
R. virens Lindh.
R. trilobata Nutt.
R. pachyrhachis Hemsl.
Garrya glaberrima Wanger
G. ovata Benth.
Arbutus xalapensis HBK.
Juniperus mexicana Spr.
Pinus cembroides Zucc.
Agave falcata Engelm.
A. americana L.
Samuela carnerosa Trel.
Nolina microcarpa S. Wats.

Arctostaphylos novoleontis Rehd.
A. pungens HBK.
Mahonia Fremontii (Torr.) Fedde
Cowania plicata D. Don
Amelanchier nervosa (Dcne.) Standl.
Philadelphus argenteus Rydb.

Broad, flat valleys frequently develop a deep, fine soil which is characteristically grassland. Such areas are common within the limits of the western montane scrub and constitute an edaphic association whose climatic significance is about equal to that of the montane scrub. In such grasslands the abundance of *Compositae* is outstanding. It is significant that any break in the continuity of the fine soil, such as a small area of gravel soil, or any break in the flat topography, such as an arroyo or a small hill, results in an abrupt change from grassland to typical montane chaparral. There follows, approximately in the order of decreasing importance, a list of the most common species comprising this grassland type.

Bouteloua gracilis (HBK.) Lag.
Buchloe dactyloides (Nutt.) Engelm.
Stipa tenuissima Trin.
Aristida Wrightii Nash
Stipa mucronata HBK.
Andropogon barbinodis Lag.
Muhlenbergia glabrata (HBK.) Kunth
Actinea linearifolia (Hook.) Kuntze
Grindelia oxylepis Greene
Applopappus spinulosus (Pursh) DC.
Verbesina stricta Gray
Hymenopappus flavescens Gray
Verbena canescens HBK.
Castilleja lanata Gray
Dyssodia puberula (Rydb.) Standl.
Thelesperma subsimplicifolium Gray
Bidens ferulaefolia (Jacq.) DC.
Salvia reflexa Hornem.
Convolvulus incanus Vahl
Eriogonum undulatum Benth.
Pentstemon tenuifolius Benth.
Stevia serrata Cav.
Pinaropappus roseus Less.
Erigeron divergens Torr. & Gray
Houstonia rubra Cav.
Helenium ooclinium Gray
Gaillardia mexicana Gray
Parosela lutea Cav.
Aristida divaricata Humb. & Bonpl.
Stipa eminens Cav.
Sitanion hystrix (Nutt.) J. G. Smith
Bouteloua curtipendula (Michx.) Torr.

The altitudinal range of the western montane chaparral is rather broad, but the zone is by no means a continuous one. The greatest concentration of the type occurs between 2,000 and 2,800 m. On xeric hogbacks and ridges it often reaches 3,000 m., but such occurrences are not of climatic indicator value. In some cases it occurs *above* well developed mesic montane forest and merges directly into subalpine forest. Such a situation results from the greater exposure of some situations of higher altitude.

g. Subalpne Humid Forest

On the upper slopes of the highest and most massive mountains, between 2,800 and 3,600 m. and rarely as low as 2,500 m., there is developed a forest of outstanding significance. It has an exceedingly simple composition, consisting usually of a single dominant tree species, two or three scattered shrubs, and a dense ground-cover of herbs. Typically the forest is dominated by *Pinus Montezumae* Lamb. In arroyos and on the very moist north slopes *Pseudotsuga mucronata* (Raf.) Sudw. and *Pinus ayacahuite* Ehrenb. become of equal importance. In the lower reaches of the zone, particularly in arroyos, shrubby species including *Quercus cordifolia* Trel., *Q. errans* Trel. f. *graciliramis* C. H. Mull., *Q. flocculenta* C. H. Mull., *Cornus stolonifera* Michx.,

Garrya laurifolia Hartw., *Salix* sp., *Holodiscus dumosus* (Nutt.) Heller, and *Rubus arizonicus* (Greene) Rydb. become quite abundant. At higher altitudes *Quercus cordifolia* and *Q. Loeseneri* Trel. are very rare while *Ribes neglectum* Rose and *Symphoricarpos microphyllus* HBK. become common. In clearings throughout the forest, whether they be natural or the result of recent cutting or merely more open forest, the abundant herbs of the forest floor grow in a profusion of species and individuals and in a luxuriance of size which far surpasses that of the herbs of any of the preceding forest types. In the following list of important herbs the species are named approximately in the order of decreasing importance. They represent perhaps thirty to thirty-five percent of the herbaceous species in this zone and have been chosen as typical of the zone because of their abundance in it and the infrequency of their occurrence in other zones or vegetation types.

Achillea lanulosa Nutt.
Pentstemon campanulatus Willd.
Lupinus elegans HBK.
Geranium mexicanum HBK.
Castilleja integrifolia L.
C. falcata Eastw.
Lupinus Muelleri Standl.
Zygadenus mexicanus Hemsl.
Sisyrinchium scabrum Cham. & Schl.
Astragalus Purpusii Jones
Delphinium valens Standl.
Lathrys eucosmus Butters & St. John
Geranium crenatum Wats.
Onosmodium unicum MacBr.
Lithospermum distichum Ortega
Dahlia variabilis Desf.
Muhlenbergia rigens (Benth.) Hitchc.
Erigeron potosinus Standl.
Grindelia inuloides Willd.
Vicia pulchella HBK.
Scutellaria Drummondii Benth.
S. spinescens Standl.
Senecio tampicanus DC.
S. umbraculiferus Wats.
Salvia Forreri Greene
Houstonia angustifolia Michx.
Museniopsis ternata (Wats.) C. & R.
Bellis xanthocomoides Gray
Viola flagelliformis Hemsl.

In the upper reaches of the subalpine forest there occur natural meadows in the forest openings as timberline is approached. The transition zone is a relatively narrow one occupying usually only about 100 vertical meters. In the meadows at this point there is a profusion of herbs similar to that of the forest below and consisting of most of the species just enumerated. There is, however, a strong influx of species from the alpine meadow above timberline so that the true subalpine meadow is composed of a mixture of species of the open subalpine forest herbs and those of the alpine meadow.

h. Alpine Meadow and Timberline

As timberline is approached there is a rather abrupt change from the most moist and most luxuriant forest in the entire region to a forest of stunted and gnarled trees openly spaced at random and finally giving way entirely to open meadow. The specific composition of the ligneous elements does not change until the timberline is actually reached. *Pinus Montezumae* in the stunted alpine form, var. *Hartwegii* Engelm., persists to the limit of tree growth. In its upper few meters of range (and exceptionally at lower altitudes) it is mixed with large shrubby forms of *P. flexilis* James and *Juniperus mexicana* Spreng. Both of the latter occur as shrubs several times broader than high and finally become mere mats as little as one foot in height. Where

finally at about 3,600 m. altitude these two species and *Pinus Montezumaa* can no longer persist, the vegetation is composed entirely of herbs which form a well developed meadow on the broad crown of the peak, occupying the upper 100 to 200 m. (in the case of Cerro Potosí, the only real alpine meadow observed). With the exception of *Pentstemon gentianoides* and *Lupinus cacuminis* the species of the alpine meadow all assume the typical low form of alpine plants, and most of them produce definite rosettes.

In the following list of herbs found in the alpine meadow the species are named approximately in the order of decreasing importance. Those preceded by an asterisk (*) are also found in the subalpine forest.

**Poa annua* L.
**Phleum alpinum* L.
Bidens Muelleri Sherff
Potentilla leonina Standl.
**Castilleja bella* Standl.
Draba neomexicana Greene
**Lupinus cacuminis* Standl.
Pentstemon gentianoides (HBK.) Don.
**Thlaspi mexicana* Standl.
Actinea Muelleri Standl.
**Phacelia platycarpa* (Cav.) Spreng.
Senecio sanguisorbae DC.
S. scalaris Greene
Cerastium brachypodum (Engelm.) Rob.
Androsace sublifera (Gray) Rydb.
**Gnaphalium Sprenglei* Hook. & Arn.

The tallest peaks are characterized by a high degree of endemism. Of the sixteen species enumerated in the preceding table six species were collected for the first times in 1934 and 1935.

X. Climatic Types

The limits of the various climatic types here distinguished are determined solely by the limits of the vegetation types described above. The correspondence is indicated in Table 1. The climatic formulae were prepared in accordance with instructions by Köppen and Geiger (1927) to collaborators in the writing of the new "Handbuch der Klimatologie." These instructions were placed in the form of a key by C. E. Koeppe and C. F. Brooks and mimeographed for class use at Clark University (1930). A copy is filed in the library of the U. S. Department of Agriculture, Washington, D. C. The formulae derived from this key do not constitute a sufficiently detailed expression of the climatic types to match the variations in vegetation. For instance, montane mesic forest and subalpine humid forest should not occupy the same climatic type (Cwbn). Either the rainfall value assigned to the latter forest is not sufficiently high, or the failure represents a weakness in the formula system.

TABLE 1

Vegetation types and climatic types of Nuevo Leon

Vegetation Types	Climatic types	Climatic formulae
a. Central plateau desert scrub	a. *Warm* and *arid*	a. BSkwg
b. Eastern coastal plain scrub	b. *Warm* and *semi-arid*	b. BShw
c. Piedmont scrub d. Montane low forest	c. *Mild* and *semi-arid*	c. Cwan
e. Montane mesic forest	d. *Cool* and *subhumid*	d. Cwbn
f. Western montane chaparral	e. *Cool* and *semi-arid*	e. BSk'w
g. Subalpine humid forest	f. *Cold* and *humid*	f. Cwbn
h. Alpine meadow and timberline	g. *Alpine*	g. ETn

The characters ascribed to each climatic type are variously determined. The climates of the eastern coastal plain and the central plateau are considered as adequately described in the treatments of them by meteorologists. They are used here as the basis of empirical estimates and of calculations by formulae of climatic factors in the mountains. Observations during the spring and summer seasons on rainfall and temperature consisted of records of the frequency and relative amounts of rainfall and the occurrence of sensibly low temperatures, frosts, etc. which are necessarily fragmentary because of constant movement from place to place. The descriptions offered by rural natives have proved most elucidating and helpful. The average Mexican peon has a very obvious consciousness of the climate in which he lives. These factors and calculations based on rainfall and temperature distributions in other similar mountains are used in the following analyses of the climatic types.

Since no direct measurements have been made in the mountains, it becomes necessary to calculate the temperatures by means of a constant factor applied to the known temperatures of the lower points. Humboldt determined the temperature gradient of the Mexican Cordillera to be –0.53° C. per 100 m. increase in altitude (Hann, l.c.). This gradient is subject to variation under various circumstances. At higher latitudes the rate is much decreased in winter, but in the area under consideration, because of its low latitude, this variation is probably of little significance. The dry or leeward side of a mountain usually has a more rapid rate of change (the difference in rate amounting to from 0.15° to 0.25° C.). Therefore, if the constant –0.53° C. were used for points on the slopes above the coastal plain stations, it would have to be increased if a central plateau station were used as the basis of calculation of the temperature of a point on the leeward or dry side of the mountains. However, the rate is much more rapid under cloudy skies than under clear skies. That means that the windward gradient would be much steeper than the leeward gradient. This nullifies in part the difference in rate due to the dry and wet sides of the mountain. That is fairly clearly shown when the temperature of a central high point is calculated from the temperatures of two known points, one to windward and one to leeward of the unknown. The calculated temperatures in the several cases tried agreed within about 1° C. of one another, the calculation from the leeward point always giving the slightly higher temperature. This can readily be accounted for by the greater abruptness of the leeward slopes in all cases except the mountains above Monterrey which have a very abrupt eastern front.

The conditions upon which the original constant of –0.53° C. per 100 m. was calculated were average conditions. Page (l.c., p. 6, fig. 11) stated the gradient between Vera Cruz and Mexico City to be –0.5° C. per 100 m. This gradient he derived from mean annual and mean monthly temperatures.

It seems reasonable that there should be some measure of agreement in the march of temperature in two closely associated points of different altitudes; so tables of calculated mean monthly temperatures are given for two of the extremely high points in the mountains.

Hernandez (18) has derived coefficients or temperature gradients of differ-

ent values for different altitudinal intervals in several regions in Mexico. In Table 2 are given the figures presented by Hernandez for those areas lying in the northeast (region 5) and southwest (region 6) of the area here studied. The increase in rate of change as altitudes become higher is readily explained by the nature of the topography. The lower elevations consist of gradual rises whereas the upper slopes are quite steep. Gradual elevation is not so efficient in producing adiabatic reduction in temperatures as is an abrupt rise. Region 6 shows higher rates of increase. This would be expected on the steeper, dry lee slope of the Sierra Madre.

TABLE 2 (from Hernandez, table 14)
Factors in altitudinal temperature gradients
Zones (in meters)

Regions	0-500	500-1,000	1,000-1,500	1,500-2,000	2,000-2,500	2,500-3,000	0-1,500
5	-0.2	-0.4	-0.5	.....	.....	.....	-0.4°C.
6	-0.3	-0.3	-0.4	-0.5	-0.6	.....	-0.3°C.

From Hernandez' figures it is obvious that a single factor will not function accurately for all regions and for all altitudes. Consequently, where temperatures are to be calculated by the altitudinal gradient method, differential factors must be used. Hernandez' figures for northeast Mexico do not include elevations above 2,500 m. From the evidence furnished by his figures for higher altitudes in southern Mexico, a series of additional factors for greater elevations have been evolved. The completed series is given in Table 3.

TABLE 3
Factors in altitudinal temperature gradients here employed
Zones (in meters)

	0-500	500-1,000	1,000-1,500	1,500-2,000	2,000-2,500	2,500-3,000	3,000-3,500	3,500& above
East slope....	-0.2	-0.4	-0.5	-0.5	-0.6	-0.6	-0.7	-0.8°C.
West slope..	-0.3	-0.3	-0.4	-0.5	-0.6	-0.7	-0.8	-0.8°C.

This modification of Hernandez' table seems to work well in calculating temperatures of unknown points in the area under consideration and is therefore the one used in this paper. In the calculation of the temperature of an unknown point, as many known temperatures as possible were employed as bases. For instance, the temperature of a centrally located high point lying between a coastal plain and a central plateau station of known temperatures would be calculated by applying to the respective altitudinal differences the corresponding series of factors in Table 3. The two calculated temperatures thus determined usually are identical, but in case of some slight disagreement, an average is employed. Should the unknown point lie on one of the slopes, its temperature would be calculated on the basis of known temperatures on the same side of the mountains.

Variations in rainfall induced by relief are not subject to reduction to a constant value as in the case of the temperature gradient. Temporary obser-

vatories in mountainous areas of other latitudes have revealed tremendous increases in precipitation (as much as 300 percent in the case of Pearson's observations in the southwestern United States). In Nuevo Leon it is obvious that a relatively mesic vegetation type indicates a much higher precipitation than that required by similar veegtation types at higher latitudes. For instance, Linares with a mean annual precipitation of 758 mm. is situated in the eastern coastal plain scrub. At latitude 40° in the United States that amount of rainfall sustains a much more mesic vegetation type. In the San Francisco Mountains in Arizona Pearson records annual precipitation in the Douglas fir and Engelmann spruce zones similar to the precipation of Linares. It is obvious that the montane mesic forests and subalpine forests of Nuevo Leon are much more mesic than the environs of Linares where corn and beans must be irrigated throughout the growing season. Not even a casual observer could avoid noticing the frequency with which thunder storms with heavy precipitation occur about the mountain peaks while the adjacent valleys and plains remain clear and dry. The writer has never seen Cerro Potosí or Cerro Infernillo past midday when they were not engulfed in a dense cloud. Several observations within such storms revealed the fact that they yield torrential rain and frequently heavy sleet.

The frequency with which these storms develop on the upper slopes of the mountains as compared with the frequency of any precipitation at all recorded by the coastal plain stations indicates that the precipitation at the tops of the peaks is at least three times that of the coasal plain and probably much more. In Table 4 it will be noted that the coastal plain stations receive some precipitation not more often than ten to fourteen days in September, the wettest month. Galeana, which is situated in an interior valley at the base of Cerro Potosí, follows fairly close the trend at Linares in number of rainy days in each month except that its total number is less. But in July, August, and September when Linares and Galeana receive a total of 27.9 and 26.6 days respectively (many of which are very light showers), Cerro Potosí is stormy every day. The writer has observed numerous rain storms at various elevations. Those of the coastal plain are frequently light showers or protracted drizzles. At altitudes of about 2,500 m. precipitations usually are heavy. Those of 3,500 m. and above are almost always heavy. A total of 92 rainy days in a period during which the coastal plain received about 27 would seem to indicate that three times the precipitation of the coastal plain is too conservative an estimate for the peak of Cerro Potosí.

TABLE 4

Number of days with any precipitation.

Month	Galeana, N. L.	Linares, N. L.	Monterrey, N. L.	Lampazos N. L.
Jan.	2.4	7.5	5.5	3.2
Feb.	2.5	4.0	5.0	2.9
March	3.3	6.1	6.6	4.5
April	5.5	11.2	7.3	5.1
May	7.8	11.5	9.0	5.3
June	8.9	11.7	8.3	3.5

July	8.8	8.0	7.7	5.2
August	6.8	5.7	7.3	3.0
Sept.	**11.0**	**14.2**	**10.5**	**8.7**
Oct.	7.1	10.2	9.0	6.6
Nov.	3.8	9.7	8.5	6.2
Dec.	4.7	15.7	6.5	6.9
Annual total	72.6	107.7	91.2	61.1

Any estimate of the annual precipitation of the highest peaks in the Sierra Madre would of necessity be arbitrary except insofar as the situation just described sets a limit below which the value could hardly be set. In view of these facts the writer is of the opinion that 2,250 mm. is a fair estimate of the average annual precipitation at the peak of Cerro Potosí. The apportionment of values to the precipitations of the lower levels is even more difficult, and the figures designated for the various zones are purely estimates.

The development of numerous rivers on the east slope and adjoining plains of the Sierra Madre and the total lack of any drainage system on the west slope is highly significant of the relative amounts of rainfall in the two regions and of the greater evaporation on the west slope. (See Pl. 6.)

a. Warm and Arid

Doctor Arroyo, Nuevo Leon, and Matehuala, San Luis Potosí, are the only two stations in the area which are truly representative of the *warm* and *arid* climatic type. Galeana lies in a broad valley just east of a low divide which cuts it off from the desert plateau. The climate of Galeana is also much influenced by the proximity of mountains which increases the rainfall in spite of the typical plateau topography of the immediate vicinity and the altitude which approximates that of the plateau. Both Doctor Arroyo and Matehuala, on the other hand, lie west of the major mountains and are consequently not so much affected.

The temperatures of this region are subject to several generalizations. On the whole they are relatively high. Calvert (l.c.) includes this area in his region of mean annual temperatures of 15° to 20° C. Undoubtedly, higher daytime temperatures occur on the plateau than are recorded east of the Sierra Madre, for the remoteness from oceanic influence and the characteristically clear skies and dry air are conditions favoring efficient insolation. For the same reasons, however, nocturnal temperatures are much lower. The proximity of the area to the southern United States and the lack of any barriers to the winter cyclones which occasionally swing so far south further lower the mean annual temperature of the central plateau. The area is well characterized by the expression *tierra templada*, with which it has been identified by numerous writers, in that it exhibits the extremes of temperatures characteristic of temperate climates.

It will be noted that although the temperatures of the central plateau average lower than those of the coastal plain, both the climates of these areas are described as "warm." Furthermore, the temperatures of the piedmont scrub and the montane low forest average higher than those of the central plateau,

but the climate of the former zones is described as "mild" as compared with that of the central plateau. This apparent inconsistency is the result of the employment of averages. Actually the daytime temperatures of the central plateau are markedly higher than those of the east slope and coastal plain. Both the diurnal and seasonal fluctuations of the central plateau are extreme with the result that in the mean annual temperature the extremely high daytime and midsummer temperatures are masked. Since the extremes are biologically more effective than the averages, the central plateau must be regarded as "warm."

Doctor Arroyo has an average annual rainfall of 486 mm. as compared with 361 mm. for Matehuala. The more westerly position of the latter station would lead one to expect a lower rainfall. From this it is probably safe to infer that the desert in the first 50 km. west of the Sierra Madre has an average annual precipitation of 50 to 100 mm. greater than that of the more centrally located points on the plateau. Since the topography of the plateau, with the exception of small isolated mountain masses, is relatively uniform, the rainfall of the entire area may, with local exceptions, be determined on the basis of these representative points.

In the following table of mean monthly precipitation for Doctor Arroyo and Matehuala (Table 5) it is evident that the season of greatest rain is June, July, August, and September, while the lowest mean monthly rainfall values occur in the winter months of December, January, and February.

TABLE 5

Mean monthly precipitation on the central plateau

Month	Doctor Arroyo, N. L.	Matehuala, S. L. P.
Jan.	* 6.7mm.	* 5.1
Feb.	*18.8	*16.0
March	21.5	15.1
April	32.5	9.4
May	43.2	21.8
June	**59.2**	**89.8**
July	**75.0**	**54.3**
August	**81.3**	**42.1**
Sept.	**78.0**	**52.8**
Oct.	29.1	16.1
Nov.	23.7	24.0
Dec.	*17.4	*13.0
Annual Total	486.4	361.5

b. WARM AND SEMI-ARID

The eastern coastal plain has been included by writers in the *tierra caliente*. Victoria with a mean annual temperature of 23.5° C. may be taken as typical. Monterrey, lying just below the upper altudinal limit of the *warm* and *semi-arid* climatic type and having a mean annual temperature of 21.8° C., may be considered as roughly marking the upper altitudinal limit of this type. Lampazos with a mean annual temperature of 22.4° C. is characteristic of the

interior lowlanws to the northwest which are representative of the coastal plain as it merges with the northern piedmont. Its greater range of temperature is suggestive of the central plateau which at this latitude is not separated from the coastal plain by a continuous range of high mountains as it is farther south. In Table 6 it may be seen that the marches of mean monthly temperatures for these three stations follow one another closely.

TABLE 6
Mean temperatures on the eastern coastal plain

Month	Victoria, Tamps.	Monterrey, N. L.	Lampazos, N. L.
Jan.	*16.9°C.	*14.3	*14.2
Feb.	*18.8	*17.0	*15.5
March	21.9	20.0	20.2
April	25.3	23.2	23.9
May	26.9	25.8	25.7
June	**28.4**	**27.6**	**29.9**
July	**28.2**	**27.6**	**29.5**
August	**28.8**	**28.0**	**30.0**
Sept.	26.9	25.5	27.2
Oct.	23.5	22.0	22.4
Nov.	21.0	17.5	17.5
Dec.	*16.5	*14.2	*13.i
Year	23.5	21.8	22.4
Abs. Max.	40.4	39.9	42.0
Abs. Min.	1.5	−1.8	−2.4

The eastern coastal plain is characterized by a much higher rainfall than is the central plateau. In Table 7 the stations are arranged in the order of location from south to north. The mean annual precipitation of the upper limit of the coastal plain *warm* and *semi-arid* zone is rather variable as may be seen by the averages obtained from Victoria, Linares, Montemorelos, Monterrey, General Bravo, and Lampazos. In general the value falls as the mountain front is followed northward. This may be explained in part by the waning of the intensity of the trade winds and in part by the greater distance of the mountains from the coast line as one moves from south to north.

TABLE 7
Mean annual precipitation on the eastern coastal plain

Station	Mean annual precipitation
Ciudad Victoria, Tamps.	706 mm.
Linares, N. L.	758
Montemorelos, N. L.	764
Villa de Santiago, N. L.	*886
Monterrey, N. L.	579
General Bravo, N. L.	548
Lampazos, N. L.	427

Villa de Santiago does not belong to this climatic type as is evidenced by the precipitation with which it is credited, the vegetation type in which it is situated, and the proximity of the station to the mountains. The other stations, however, are sufficiently distant from the mountains to be charac-

teristic of the *warm* and *semi-arid* climatic type. Lampazos, on the other hand, is so far north and west that the rainfall shows continental influence.

In the following table of mean monthly precipitations (Table 8) the rainy season is very evidently divided by a midsummer dry season, while the period of minimum precipitation, like that of the central plateau, falls roughly in the winter months of December, January, and February.

TABLE 8

Mean monthly precipitations on the eastern coastal plain

Month	Victoria, Tamps.	Linares, N. L.	Montemorelos, N. L.	Monterrey, N. L.	Gen. Bravo, N. L.	Lampazos, N.L.
Jan.	*17.0	*19	*21.3	*14	* 7.9	*15mm.
Feb.	*28	*16.7	*26.4	*18	* 3.2	*17
March	34	*29.7	35.1	21	21.0	*16
April	40	72.1	*79.4*	33	43.4	28
May	**107**	96.6	61.2	34	**85.6**	26
June	**113**	**123.0**	**79.0**	**77**	**100.5**	23
July	61	57.8	66.2	58	70.3	**45**
August	78	39.4	**107.5**	60	61.9	16
Sept.	**126**	**143.1**	**119.6**	**131**	**68.0**	**110**
Oct.	57	68.5	63.9	75	27.0	58
Nov.	25	61.3	75.8	38	41.3	48
Dec.	*20	*31.1	*28.2	*20	18.0	*25
Annual total	706	758	764	579	548	427

c. MILD AND SEMI-ARID

The climatic factors of the lower altitudinal reaches of the *mild* and *semi-arid* zone are very well characterized by the data collected by the meteorological observatory at Villa Santiago. However, the piedmont scrub and the low montane forest to which this climatic type is limited have a vertical range of about 1,000 m. There results a marked decrease in temperature and increase in precipitation as greater altitudes are reached.

Lampazos, Nuevo Leon, at 317 m. altitude, is taken as the basis for calculating the temperatures of the piedmont area in the north of Nuevo Leon. The mean annual temperature of Lampazos is 22.4° C. The calculated mean annual temperatures of the piedmont then would be 20° to 22° C. for the area lying between 500 and 1,000 m. and as low as 17.5° C. for the level of 1,500 m. Using the Monterrey mean annual temperature as a basis, the 1,500 m. level in the mountains above Monterrey would have a mean annual temperature of 17.3° C., while that of the 1,500 m. level based on the data of Victoria, Tamps., would equal 18.7° C. The piedmont and lower slopes belonging to the *mild* and *semi-arid* climatic type, then, may be said to be characterized by mean annual temperatures ranging approximately between 17.5° and 22° C.

Since it has been shown above that in this area latitude is in a measure responsible for a decrease in precipitation from south to north, that factor must be taken into consideration in assigning precipitation values to the zones lying immediately above the coastal plain. The average annual rainfall of

the *mild* and *semi-arid* climatic type is estimated to be as follows: northern piedmont, 500 to 1,000 mm.; northern lower mountain slopes, 550 to 1,200 mm.; southern lower mountain slopes, 700 to 1,200. mm.

d. Cool and Subhumid

The mesic forest which characterizes this type occurs at different levels on the two sides of the mountains. On the windward side it is developed at relatively low altitudes (as low as 1,500 m.) in rather warm situations. On the leeward side, however, it seldom develops below 2,500 m. and therefore occurs only in relatively cool habitats. The eastern temperature range of this type falls between 10° and 18° C. while the western range is about 9.5° to 13° C. Rainfall in this area is calculated to lie between 1,200 and 1,800 mm. per year.

This zone, of all the climatic types here distinguished, most nearly approximates the temperate region of the United States. It is true that the latitudinal position of the region does not allow the marked seasonal fluctuation in temperature which is so characteristic of temperate regions. However, there exists a very definite winter period during which protracted freezes occur, and the temperature falls several degrees below freezing. Similarly, in summer there is a period of relatively high temperatures. The rainfall, however, is sufficient for the growth of wheat, corn, cucurbits, small fruits, and vegetables. These are grown without irrigation and seldom are harmed by drought. The growing season is relatively short, for spring frosts are quite frequent even as late as the last week in May, and very little growth occurs before the end of May.

e. Cool and Semi-arid

The *cool* and *semi-arid* climatic type is based on the occurrence of an evergreen shrubby growth on the lee side of the mountains. This is a rain-shadow location, and the resulting lower precipitation is probably significantly correlated with the high proportion of broad-sclerophyll plants. Specific composition of the numerous plant assemblages is highly variable, but in practically all of these, evergreen shrubs of xeromorphic appearance are prominent. Grasslands are interspersed through the chaparral zone where fine deep soils locally replace the prevailing coarse, shallow soils of the chaparral.

The normal vertical range of this chaparral type is about 800 m. Outposts occur as high as 3,000 m. in locally more xeric habitats on certain ridgetops. Under such conditions chaparral exists in the *cold* and *humid* climatic type which is characterized by subalpine humid forests. The temperatures which have been calculated for the *cool* and *semi-arid* zone are from 16.5° C. at 2,000 m. altitude to 11° C. at 2,800 m. altitude. The relative constancy of growth form throughout the area suggests that the rainfall may have a somewhat narrow range. The mean annual rainfall of this climatic type is calculated to fall between 750 and 1,000 mm.

The close vegetational resemblance to California chaparral is not indicative of a California climatic type. The Nuevo Leon chaparral receives its major

rainfall from June to September, but an element in common to both regions may be mild winter temperatures.

f. Cold and Humid

The mean annual temperatures calculated for this climatic type range between 4.5° and 13° C. On the western edge of the Sierra Madre this type seldom reaches a sufficiently low altitude to have a mean annual temperature greater than 11° C., but some of the more prominent eastern peaks have such a heavy rainfall that the forest type upon which this climatic type is based is developed at altitudes as low as 2,500 m. which have somewhat higher temperatures.

The extremely low temperature with which this type is credited is not surprising to one who has visited the area for any length of time. On Cerro Potosí at an altitude of approximately 3,000 m. early morning frosts were observed on four mornings out of ten in July. The temperature rose rapidly after sunrise, but never was high enough to cause discomfort even to one wearing heavy clothing. The plants, at the height of their blooming season, apparently were entirely unharmed by the frost.

This zone falls very near the point of maximum rainfall in the Sierra Madre Oriental. In some areas within its limits occur the most mesic conditions anywhere encountered in Nuevo Leon. Flat meadows even in the lower reaches of the zone are so soggy that cultivation is impossible except around the well drained edges where potatoes and wheat are grown. The mean annual rainfall of this climatic type is estimated to be between 1,800 and 2,200 mm.

g. Alpine

The upper 200 m. of one peak (Cerro Potosí, altitude 3,800 m.) and probably the extreme top of Peña Nevada (altitude 3,660 m.) fall in this type. The mean temperatures calculated for the tops of these two peaks are given by months in Table 9. The figures are corrected for the temperature gradient difference between windward and leeward slopes as indicated in Table 3.

Table 9

Mean monthly temperatures of the alpine zone

Month	Cerro Potosí (based on Galeana, N. L.)	Peña Nevada (based on Victoria, Tamps.)
Jan.	−2.2	−1.1
Feb.	−0.7	0.8
March	1.6	3.9
April	4.6	7.3
May	6.5	8.9
June	6.3	10.4
July	6.4	10.2
August	5.7	10.8
Sept.	5.4	8.9
Oct.	3.4	5.5
Nov.	1.0	3.0
Dec.	−0.9	−1.5
Year	3.1	5.5

The mean annual temperature of 3° C. is by no means low for this climatic type. The frequency of clouding (interrupted insolation), the rapid cooling, and the frequency of snow or sleet, midday air temperatures below freezing, etc., within the warmest months suggest an even lower mean. Apparently the rapidly growing herbs are unharmed by an almost daily coat of ice and, when the ice is melted a few hours later, continue with open blooms as lowland plants might after a light shower of rain.

Rainfall at this level is by no means diminished as the name of the vegetation might suggest. In the upper few hundred meters of the peaks occurs the heaviest and most frequent rain in the entire region. It is calculated that the mean annual precipitation of this zone amounts to 2,250 mm. The obvious xerophytism of the vegetation type is therefore not the result of decreased rainfall but rather is caused by the more rapid rate of run-off, the tremendously increased evaporation which is the result of the greater evaporating power of the rarified air at high altitudes, and the higher wind velocity about the peak. The soil at this level is usually washed thin and exceedingly well drained.

XI. Distribution of Vegetation Types and Climatic Types

The location and extent of the eastern coastal plain scrub and of the central plateau desert scrub with *warm* and *semi-arid*, and *warm* and *arid* climatic types respectively have been sufficiently described. The higher zones, then, remain to be discussed. The piedmont scrub in northwestern Nuevo Leon occurs in scattered localities over an area ranging 1° in longitude and 2° in latitude. It extends south along the east face of the mountains in a continuous, narrow strip corresponding to the lower foothills. A few of the more prominent rises on the northern piedmont develop montane low forest, but this vegetation type reaches its best development on the lower eastern slopes of the mountains where, because of the gentle rise at most latitudes, it occupies a strip 2 to 20 km. in width. The *mild* and *semi-arid* climatic type therefore has a range which follows the east face of the mountains north to the piedmont province where it spreads to almost half the width of the state.

The western montane scrub has a much broken range. Elements of this vegetation type may be found on the west slopes of salient eastern peaks, but the greatest development occurs in the western half of the mountain area where foothills and low mountains above the desert plateau lead up to the high mountains. Outlying low mountains on the plateau also bear this type. Its discontinuous range, and the identical range of the *cool* and *semi-arid* climatic type which it indicates, have an average width of about 10 km.

The mesic montane forest with the *cool* and *subhumid* climatic type reaches its fullest development in three major areas. In the mountains at Monterrey and to the south for a distance of perhaps 100 km. to the skirts of Cerro Potosí, the vicinity of Hacienda Pablillo southeast of Galeana, and the vicinity of Peña Nevada east of Doctor Arroyo are the principal areas. Smaller areas on isolated high slopes are common.

The subalpine humid forest with its accompanying *cold* and *humid* climatic type is a much more restricted type. Its principal development occurs on the slopes of Cerro Potosí and the highest peaks to the north of Potosí. Peña Nevada and a few minor peaks to the east also bear this type, and it is quite extensive on Cerro Infernillo on Hacienda Pablillo southeast of Galeana.

The extreme top of Cerro Potosí and possibly a similar spot on Peña Nevada bear alpine meadow with which the *alpine* climatic type is associated.

The maximum width of the area bearing vegetation and climatic types different from those of the plateau and coastal plain (exclusive of the northern piedmont) is just under 100 km., while the minimum width of this composite zone is about 50 km. The total area in which new climatic types are proposed involves more than one-fourth the area of the entire state. (See Pl. 7.)

XII. Summary

The dependence of plant growth and the development of vegetation types upon climate has been shown by numerous writers. On the basis of this dependence, edaphic influences having been taken into account, it is assumed that vegetation types and climatic types of Nuevo Leon, Mexico, coincide in range.

The variations of climatic factors with altitude, topography, etc. follow a set of laws and result in the occurrence in general of cooler and more humid climates at higher altitudes and on more abrupt slopes. This coincides with the occurrence of vegetation types in the Sierra Madre of Nuevo Leon.

The lowland climates of Nuevo Leon are fairly well known. The climatic factors of the various vegetation types in the mountains above the existing meteorological observatories are extrapolated by application of the rules of climatic variation in mountains to the data collected by government observatories in the lowlands. Eight major vegetation types are recognized and on them are based seven climatic types.

a. Central plateau desert scrub.—This vegetation type is one of widely spaced thorny shrubs with few herbs save in the rainy season. It occurs west of the Sierra Madre up to altitudes of 2,000 m. The climatic type is called *warm* and *arid* (BSkwg) and is characterized by mean annual temperatures ranging from 15° to 20° C. and mean annual precipitation ranging about from 360 to 485 mm., the higher figure occurring near the mountains.

b. Eastern coastal plain scrub.—This type differs from the plateau type in having fewer thorny species, the shrubs more luxuriant and closely spaced, and a greater abundance of herbs (particularly grasses). It occupies the lowlands to windward (east) of the mountains and reaches an elevation of 500 m. This climatic type is called *warm* and *semi-arid* (BShw). It is characterized by mean annual temperatures ranging about from 21° to 25° C. The mean annual precipitation ranges roughly between 425 and 775 mm. The lower precipitation values occur in the north where the mountains are farther from the Gulf Coast.

c. Piedmont scrub.—This shrub type incorporates some of the species of the coastal plain with additional nonthorny species many of which reach small-tree size and are more densely grouped. It occurs on the low rise which occupies the northwestern sector of the state and functions to the south as a narrow transition zone between the coastal plain and the lower slopes of the mountains.

d. Montane low forest.—At altitudes of 750 to 1,000 m. on the east slopes of the Sierra Madre the piedmont scrub gives way to a low forest composed principally of *Quercus, Juglans, Carya,* and numerous shrubs. The trees are low, gnarled, and widely spaced so that herbaceous ground cover, especially of grasses, is abundant. This type persists usually to an altitude of 1,500 m. The piedmont scrub and the montane low forest have been combined in a single climatic type designated as *mild* and *semi-arid* (Cwan). This climate is characterized by mean annual temperatures ranging between 17.5° and 22° C., while its mean annual precipitation is estimated in the northern piedmont to be 500 to 1,000 mm.; northern lower mountain slopes, 550 to 1,200 mm.; southern lower mountain slopes, 700 to 1,200 mm.

e. Montane mesic forest.—This forest consists of pines, *Pseudotsuga,* mesic oaks, and shade-tolerant shrubs densely spaced and developing tall, slender trunks on which sometimes large epiphytic bromeliads are abundant. The dense shade limits the growth of any but a few shade-tolerant herb species save in more open woodland or in clearings where the herbs become luxuriant. This is the first zone so far discussed in which the summer drought does not produce a cessation of herb growth. The altitude range is roughly 1,500 to 2,800 m., but the type is developed at the lower altitude only on the east slope of the mountains, while on the west slope it does not occur below 2,500 m. The climate of the area occupied by mesic forest is designated as *cool* and *subhumid* (Cwbn). Its mean annual temperature ranges between 9.5° and 13° C., while the mean annual rainfall approximates 1,200 to 1,800 mm.

f. Western montane chaparral.—This vegetation type is suggestive of the California chaparral in the many evergreen species which comprise it. It is exceedingly heterogeneous but is constant in the shrub habit of its usually evergreen species and the density of its growth. Its altitudinal range is from 2,000 m. at the edge of the plateau desert up to the western or leeward slopes of the Sierra Madre to the 2,800 m. level. The climate of this area is designated as *cool* and *semi-arid* (BSk'w). Its mean annual temperature range is from 11° to 16.5° C. while its mean annual precipitation is calculated to range between 750 and 1,000 mm.

g. Subalpine humid forest.—This forest type is developed over limited areas on the slopes of the higher mountains ranging between 2,500 and 3,600 m. altitude, though it seldom descends below 2,800 m. The forest is characteristically dominated by a single species, *Pinus Montezumae,* and has an exceedingly dense and luxuriant herb layer. Shrubs are sparse and few in numbers of species. The climate of this forest is termed *cold* and *humid*

(Cwbn). The mean annual temperature ranges between 4.5° and 13° C., while the mean annual precipitation is calculated to be between 1,800 and 2,200 mm.

h. Alpine meadow and timberline.—The alpine meadow consists of numerous low herbs, most of them rosette-forming, which densely cover the peak and slopes of the tallest mountains above an altitude of about 3,600 m. Its lower extremities alternate with matted, scrubby *Pinus flexilis* and *Juniperus mexicana* and stunted *Pinus Montezumae* which constitute the upper limit of tree growth. The climate of this zone is designated as *alpine* (ETn). The rainfall is the highest in the region. The obvious xeric character evidenced by the stunting of the trees is the result of the tremendous evaporating power of the freely moving, rarified atmosphere and the higher percentage of run-off of the peaks. The mean annual temperature is calculated to be about 3° to 4.5° C., while the mean annual precipitation is estimated at 2,250 mm.

The area occupied by the new climatic types here proposed for this region comprises more than one-fourth the total area of the state of Nuevo Leon.

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XIV. EXPLANATION OF PLATES[3]

Plate 1. Fig. 1.—Central plateau desert scrub in western Nuevo Leon consisting of *Larrea divaricata*, *Fouquieria splendens*, *Agave falcata*, etc. with no ground-cover between the shrubs.

Fig. 2.—Central plateau desert scrub in western Nuevo Leon showing the concentration of shrubs into a thicket in favorable sites. *Yucca* sp., *Larrea divaricata*, *Opuntia imbricata*, and *Agave falcata* are the principal species.

Fig. 3.—A typical landscape in the central plateau desert scrub.

Plate 2. Fig. 1.—Eastern coastal plain scrub in north central Nuevo Leon consisting of *Cordia Boissieri*, *Opuntia* sp., *Yucca* sp., *Celtis pallida*, etc. Note the grass cover in the foreground.

Fig. 2.—Piedmont scrub composed of *Quercus fusiformis*, *Dasylirion* sp., *Acacia amentacea*, *Leucaena glauca*, *Opuntia* sp., etc. Note the greatly increased density of the shrubs.

Fig. 3.—Montane low forest in the Sierra Madre of Nuevo Leon. The dominant tree is *Quercus clivicola* beneath which *Agave americana* and several species of grass are abundant. Note the low trees and wide spacing.

Plate 3. Fig. 1.—Western montane chaparral on Cerro Potosí composed of *Quercus flocculenta*, *Juniperus mexicana*, *Pinus cembroides*, *Rhus virens*, *Cercocarpus majodensis*, *Ceanothus ferox*, *Agave americana*, *Garrya ovata*, etc.

Fig. 2.—Montane mesic forest in the Sierra Madre of Nuevo Leon. The forest in the foreground and middle distance is an almost pure stand of *Pinus teocote* and *P. pseudostrobus*.

Fig. 3.—Subalpine forest of *Pinus Montezumae* on Cerro Potosí. Note the luxuriant subalpine meadow in the foreground.

Plate 4. Fig. 1.—Timberline on Cerro Potosí. The woody growth is composed of *Juniperus pachyphloea*, *Pinus flexilis*, and (in the distance) *P. Montezumae*.

Fig. 2.—*Pinus ayacahuite* on Cerro Potosí with *P. Montezumae*. Note the dense growth of herbs in the opening.

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3 Additional landscape photographs illustrating the vegetation of this area have been published by the author in the American Midland Naturalist **18**:997-1,000. 1937.

PLATE 1

PLATE 2

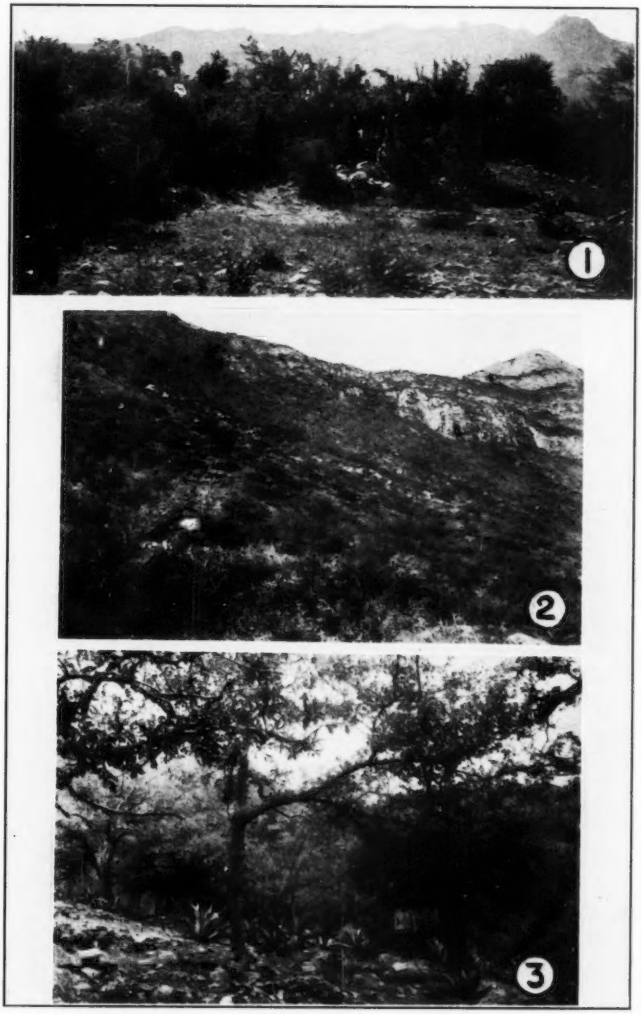


PLATE 3

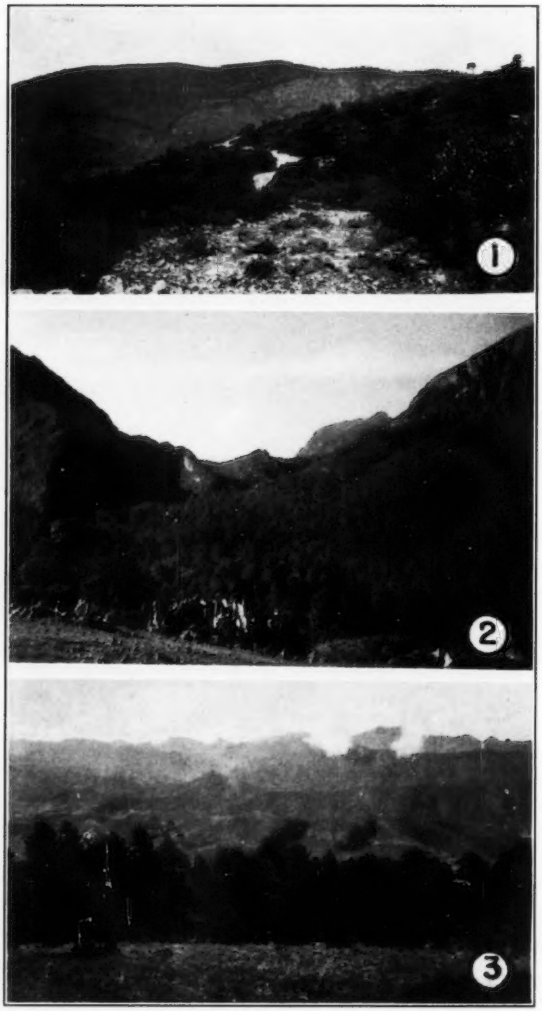
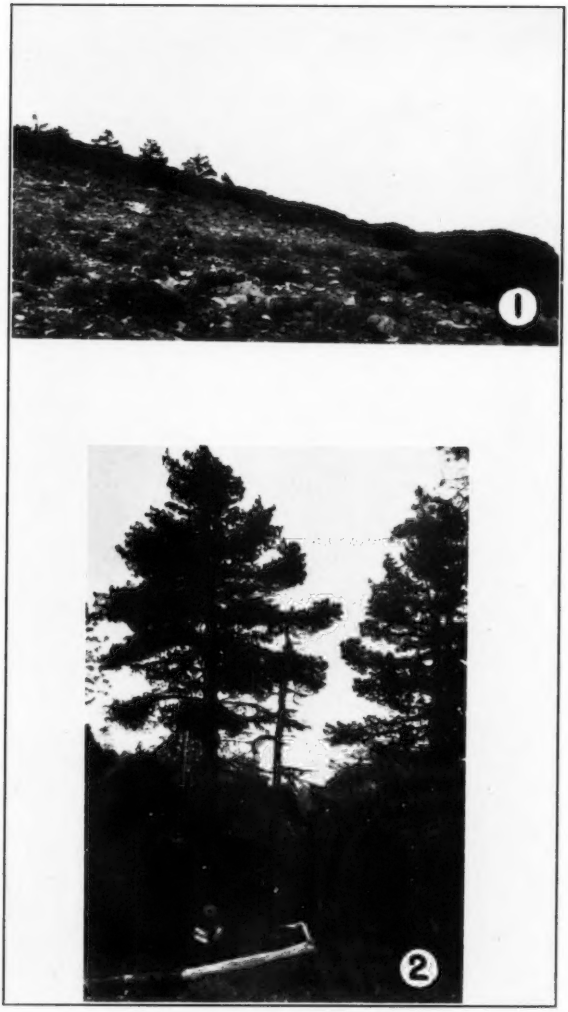


PLATE 4



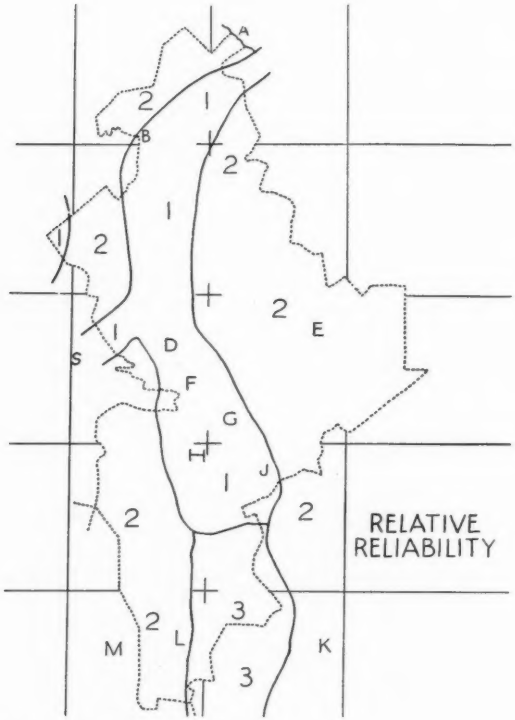


PLATE 5. Relative reliability. Regions:

1. Areas studied in detail (include most of the mountains).
2. Areas observed in part; classified on the basis of similarities of topography.
3. Area not observed; classified on the basis of similarities of topography and fragmentary reports of the vegetation (includes a part of the mountains).

Localities:

A. Laredo, Texas	F. Villa Santiago, N. L.	K. Victoria Tamaulipas
B. Lampazos, N. L.	G. Montemorelos, N. L.	L. Doctor Arroyo, N. L.
D. Monterrey, N. L.	H. Galeana, N. L.	M. Matehuala, San Luis Potosí
E. General Bravo, N. L.	J. Linares, N. L.	S. Saltillo, Coahuila

PLATE 6. Relief of Nuevo Leon. In the extreme south and in the west-central portions of the area are drawn arbitrary lines separating the 1,000 to 2,000 m. zone of the east slope from the 1,500 to 2,000 m. zone of the central plateau. In these areas occur gradual transitions from east slope to plateau physiography which are not altogether altitudinal.

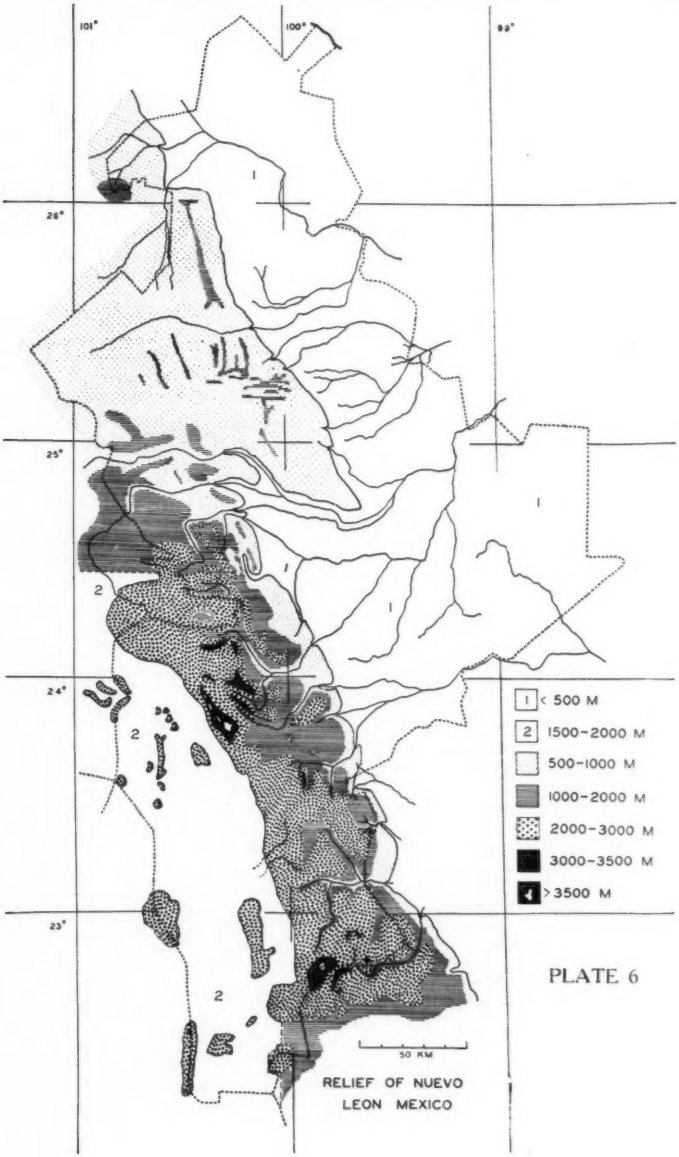
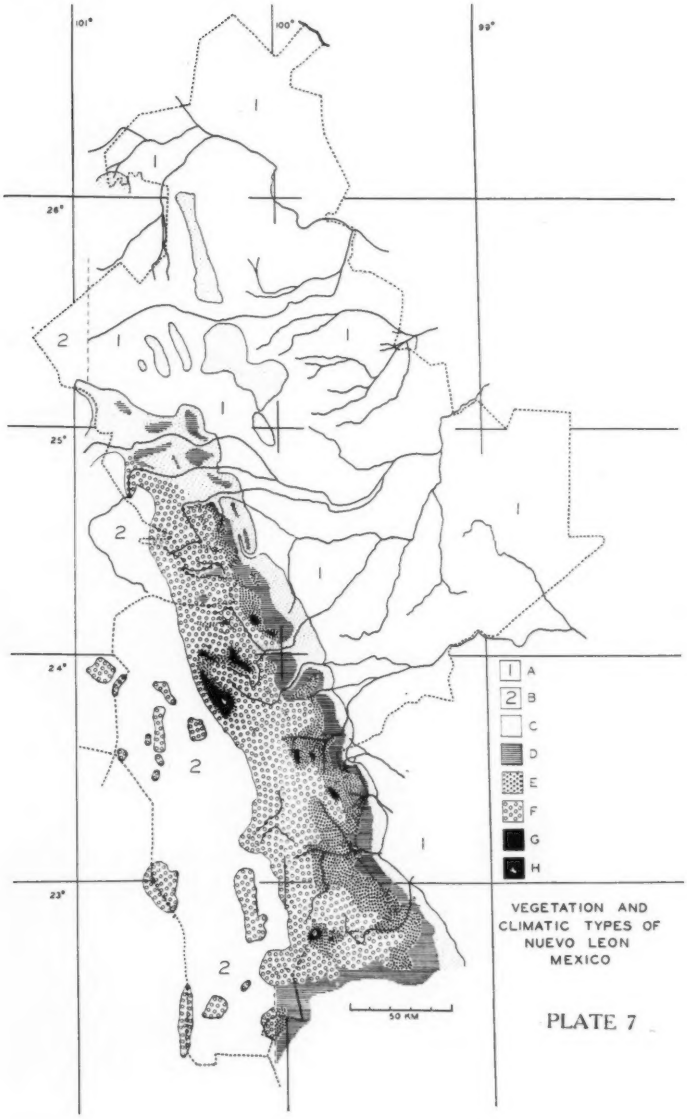

101°
100°
99°
26°
25°
24°
23°
1
2
< 500 M
1500–2000 M
500–1000 M
1000–2000 M
2000–3000 M
3000–3500 M
> 3500 M
50 KM
RELIEF OF NUEVO
LEON MEXICO

PLATE 6

PLATE 7. Vegetation and climatic types of Nuevo Leon.

A.—Eastern coastal plain scrub with a *warm* and *semi-arid* climatic type (BShw).
B.—Central plateau desert scrub with a *warm* and *arid* climatic type (BSkwg).
C.—Piedmont scrub with a *mild* and *semi-arid* climatic type (Cwan).
D.—Montane low forest also comprising a part of the *mild* and *semi-arid* climatic type (Cwan).
E.—Montane mesic forest with a *cool* and *subhumid* climatic type (Cwbn).
F.—Western montane chaparral with a *cool* and *semi-arid* climatic type (BSk'w).
G.—Subalpine humid forest with a *cold* and *humid* climatic type (Cwbn).
H.—Alpine meadow with an *alpine* climatic type (ETn).

In the extreme south is drawn an arbitrary line separating the montane low forest from the central plateau desert scrub. In the northwest a similar line separates the eastern coastal plain scrub from the central plateau desert scrub. In both cases the transition is a gradual one and can hardly be represented as have been the boundaries between other vegetation types in this area.



VEGETATION AND CLIMATIC TYPES OF NUEVO LEON MEXICO

PLATE 7

Geographical Affinities of the Flora of Ohio

Isabel Thompson

The affinities of the flora of any region are the product of past geologic and climatic history and of present edaphic and climatic conditions. A change in any of the above will bring about shifts or migrations of floras. The present geographic distribution of a species, though in the main a reflection of existing climatic and edaphic conditions, may be due in part to past migrations. The flora of Ohio can be explained only if these dynamic agents are taken into consideration. In the past there has been a series of migrations of unrelated floristic elements depending upon the changing conditions. The persistence of a species after there has been a modification of any of the causal factors, has led to the intermingling of different elements in our flora.

Grateful appreciation is accorded Dr. E. Lucy Braun for valuable aid given the writer. Credit is due the late Dr. J. H. Schaffner for unpublished data concerning the distribution of certain plants.

Geology and Physiography

There are three physiographic provinces represented in Ohio, the Appalachian Plateau, the Central Lowland, and the Interior Low Plateau (Fig. 1).

Eastern Ohio, a maturely dissected plateau, is part of the Allegheny

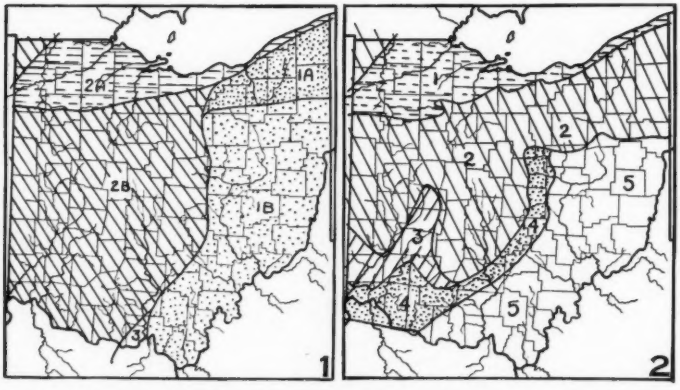


Fig. 1. Physiographic Map of Ohio. Adapted from Fenneman (1917). (1a) Glaciated Allegheny Plateau, (1b) Unglaciated Allegheny Plateau, (2a) Northern Section of Central Lowlands, (2b) Till Plains of the Lowlands, (3) Interior Low Plateau.

Fig. 2. Glacial Map of Ohio. Adapted from Leverett (02). (1) Lake Plains, (2) Early Wisconsin Drift, (3) Late Wisconsin Drift, (4) Illinoian Till Plains, (5) Unglaciated Area.

Plateau, a section of the Appalachian Plateau. The northern part has been glaciated (Fig. 2) but the physiographic features, in the main, are preglacial. The underlying strata, sandstones, shales, and limestones, are generally horizontal. The Plateau is capped with strata mainly Carboniferous in age. At the western margin of the Plateau is a prominent escarpment which forms the boundary between this province and the Central Lowland and the Interior Low Plateau to the west.

Somewhat more than the western half of the state is in the Central Lowland. The sections of this physiographic province in Ohio, the Northern Section and the Till Plains, vary as to the effects of glaciation and the degree of subsequent erosion. The Northern Section covers essentially the area occupied by glacial Lake Maumee. The underlying rocks are mainly limestones. They are covered in part by lacustrine deposits which border Lake Erie and in part by areas of deep drift with numerous moraines, lakes, and swamps. The Till Plains extend south from the lake plains to the Ohio River. The drift varies from a few feet to a few hundred feet in thickness. The ground moraine is but little dissected and obscures the preglacial topography and the underlying limestone almost everywhere.

The Interior Low Plateau extends into southern Ohio from the south as a wedge between the Central Lowland and the Allegheny Plateau. It is unglaciated and more dissected than the Central Lowland, though of about the same elevation. The underlying rock is limestone and calcareous shales.

Succession of Events

Ohio became land area at the end of Paleozoic. During Mesozoic and Tertiary it was open for plant occupany and migration.

In Tertiary times Ohio was part of a deciduous forest which was more widespread than the present one. The gradual separation of this forest into southern and northern types was effected in Late Tertiary and early Pleistocene. By this time the prairie had developed to the west of Ohio. The pattern of distribution of the major vegetational types was hence similar to that of today.

At least two major periods of glaciation, the Illinoian and the Wisconsin, have influenced the vegetational history of Ohio. During each period the flora migrated south of the glacial border. Probably narrow belts of Arctic plants and conifer forests occupied the margins of the glaciers with deciduous forests but a short distance to the south. In the interglacial periods migrations northward took place, reestablishing vegetation on the glaciated area.

The glacial map (Fig. 2) shows that a considerable portion of the southeastern part of the state was never glaciated. The unglaciated region probably has been occupied by vegetation continuously since Tertiary.

The glaciated part of the state contains areas of various ages. The oldest of these is the Illinoian Till Plains, an area exposed to the north of the unglaciated region. Neither the Early nor the Late Wisconsin glaciation was as extensive as the Illinoian. However, more area of the Late Wisconsin drift is exposed than any of the earlier glaciations so that more evidence of

the vegetational history of that region still persists. The youngest section of the state is the northern part along Lake Erie, the area of the glacial Lake Maumee.

Conditions for plant growth and migrations have not been uniform since the retreat of the last glacier. Studies made by Sears (1932, 1935) on the pollen of bogs indicate that there has been at least six separate periods in the post glacial climate of Ohio. The first was a cool humid period which favored the development of fir and spruce. This was followed by one in which the climate was cool but it is uncertain whether it was dry or humid. The third was dry and cool in which there was considerable development of pine. In the moderately warm and humid period which came next a beech and mixed deciduous forest was established. The climate continued warm but later became dry so that an eastward extension of the prairie and of oak-hickory forest was favored. This post-Wisconsin xerothermic period with the extension of the prairie into Ohio temporarily halted the northward migration of the deciduous forest. There is evidence that the deciduous forest was able to extend itself somewhat in the xerothermic period by going around the prairie lobe (Gleason, 1922). However, as conditions again became more humid, the forest invaded the prairie communities. The present extent of the prairie communities in Ohio is not great but they are so distributed as to indicate the presence of a former more continuous lobe.

The Flora of Ohio

The relic communities of Ohio are expressions of the past floras of the state. The relic communities of the various age areas of the state afford very important evidence as to the migrations which have taken place since each of these was opened for plant occupancy and migration.

Relic communities are not limited to the glaciated sections of the state, but are also found on the unglaciated. The xerophytic prairie communities of Adams County have been interpreted as representing a former and more widespread lobe of the prairies in pre-Illinoian times (Braun 1928). The boreal relics of the unglaciated area are near the margin of the Illinoian drift. They are believed to be relics of the coniferous forest belt found in Ohio following Illinoian glaciation. These boreal relics have been able to persist in places not favorable for the establishment of the deciduous forest vegetation.

There are two types of relic communities on the Illinoian drift, prairie and boreal colonies. The prairies are quite limited in extent and are considered post-Wisconsin in age. The boreal colonies are found in parts of Clinton, Clermont, Brown, and Highland Counties which were not effected by Wisconsin glaciation. The land is undissected and the soil impervious so that relatively moist habitats have probably prevailed there even during the Wisconsin xerothermic period.

On the Wisconsin drift there are both mesophytic prairie colonies and boreal relics. The prairie communities are interpreted as remnants of the former more continuous prairie lobe of the post-Wisconsin xerothermic period. The numerous hydrophytic boreal relics followed the retreating Wisconsin

glaciers northward and have survived the post-Wisconsin xerothermic period in extreme habitats such as bogs.

The present flora of Ohio is predominantly that of the deciduous forest. According to Schaffner's Catalogue (1932), there are more than fifteen hundred native vascular plants in the state, exclusive of the Gramineae and the Cyperaceae, which are not included in the present study.

The native flora is interpreted as composed of a number of floristic elements, each displaying certain general types of distribution both in Ohio and the United States as a whole. Although the general characteristics of each group are distinctive, no clear cut lines between the various elements can be drawn.

Ohio is interesting floristically because of its location. Its northern boundary is near the hemlock-white pine-northern hardwood forest and not far from the great northern coniferous forest. Part of Ohio is in the Allegheny Plateau, a section of the Appalachian region. Ohio is not far from the great prairies of the west. The alluvial plains of the Ohio River form an unbroken connection with the Mississippi Embayment, permitting the northward migration of Mississippi Embayment species into the southern part of the state. In the past, connections have existed between the Great Lakes and the Atlantic Coastal Plain. Along these connections coastal plain species have entered into the state and a small number of them still occur along the northern lake plains. The flora of Ohio is composed of species of all these various regions in addition to the more widespread species.

The following table lists the various floristic elements of the state with the types of species in each and the approximate proportion of the native flora they compose.

NATIVE FLORA OF OHIO

I. Widespread species	60%
A. Eastern United States species	45%
B. General United States species	9%
C. Interior United States species	6%
II. Disjuncts or species near the margin of their ranges	40%
A. Northern Element	12%
1. Northern species	
2. North-northeastern species	
B. Appalachian Element	10%
1. Appalachian species	
2. Appalachian and Ozark species	
3. Interior and Ozark species	
C. Southern Element	8%
1. Species of southern United States	
2. Southern interior species	
3. Far southern species	
D. Coastal Plain Element	4%
1. Species of the Coastal Plain and adjacent provinces	
2. Species of the Coastal Plain and Great Lakes	
3. Mississippi Embayment species	
E. Western Element	6%
1. Upland prairie species	
2. Lowland prairie species	

I. Widespread Species

About sixty percent of the native flora of Ohio is composed of species which are not only present in many counties of the state, but are also general in adjacent states. These show three general types of ranges in the United States, those of eastern United States, those general over much of the United States in suitable habitats, and those of interior United States.

The species which display the first type of distribution make up forty-five percent of the native vascular flora of the state and are essentially plants of the deciduous forest. Some of them range west into the grasslands while others are more limited. Species showing this general type of distribution include *Juglans nigra, Fagus grandifolia, Ulmus americana, Liriodendron tulipifera,* and *Asarum canadense.* Species which are general over much of the United States compose about nine percent of the native vascular flora of the state. Examples are *Botrychium virginianum, Typha latifolia, Ranunculus abortivus,* and *Smilacina racemosa.* The species with an interior United States distribution constitute about six percent of the flora. These are concentrated mainly west of the Appalachian Mountains and may range as far west as Texas, Kansas, and Nebraska. Examples of species of the interior United States are *Sedum ternatum* and *Jeffersonia diphylla.*

II. Disjuncts or Species at the Margin of Their Ranges

A. *Northern Element*

The largest group of species which are near the margin of their ranges in Ohio is the northern element, composed of about twelve percent of the native flora of the state. This is not a homogeneous group but is composed of species with two types of ranges.[1] The majority are plants of the northern part of the continent not occurring in the eastern part of the United States south of southern New York, New Jersey, or Pennsylvania, and here called "northern species." The second group comprises a smaller number of species. While these are concentrated mainly in the north, they occur also in the mountains of eastern United States as far south as North Carolina and Georgia and will be referred to as the "north-northeastern species." Most of the species of these two groups are transcontinental in range. The others do not extend west of the Rocky Mountains, in fact many reach their western limits in Ontario and Manitoba.

1. *Northern species.*—A smaller number of the transcontinental northern species found in Ohio are circumboreal. *Potentilla palustris* (Fig. 3) is common in bogs on the North American continent from Labrador north to Greenland and the Arctic.[2] *Menyanthes trifoliata* and *Lathyrus palustris* (Fig.

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1 Ranges for the various species were taken from Manuals: Gray (1908), Britton and Brown (1913), Small (1933), Rydberg (1932), Macoun (1883), and Pennell (1935).

2 The Ohio distibutions of species in this paper were taken from the *Revised Catalogue of Ohio Vascular Plants* and the various *Additions to the Revised Catalogue of Ohio Vascular Plants* by J. H. Schaffner, supplemented by published and unpublished records from the University of Cincinnati.

4 and 5) are plants of bogs and lakes which are usually much farther north than Ohio.

The transcontinental northern species which are confined to boreal North America are more numerous than the circumboreal species. *Shepherdia canadensis, Hypericum majus, Ledum groenlandicum,* and *Salix pedicellaris* (Fig. 6 to 9) have distributions in Ohio which are characteristic of the group. *Ledum groenlandicum* was probably planted on Cranberry Island, Buckeye Lake, Licking County (Schaffner 1932).

Figs. 3-19. Northern Species in Ohio. Fig. 3-5 Circumboreal. 3. *Potentilla palustris*, 4. *Menyanthes trifoliata*, 5. *Lathyrus palustris*. Figs. 6-9 North American Boreal Species. 6. *Shepherdia canadensis*, 7. *Hypericum majus*, 8. *Ledum groenlandicum*, 9. *Salix pedicellaris*. Figs. 10-19 Northern Coniferous Forest Species. 10. *Linnaea americana*, 11. *Pyrola secunda*, 12. *Betula papyrifera*, 13. *Rhamnus alnifolia*, 14. *Betula pumila*, 15. *Alnus incana*, 16. *Larix laricina*, 17. *Salix candida*, 18. *Epipactis tesselata*, 19. *Aster lindleyanus*.

The transcontinental northern coniferous forest species are represented in Ohio by *Linnaea americana, Pyrola secunda, Betula papyrifera,* and *Rhamnus alnifolia* (Fig. 10 to 13).

Northern species which do not extend beyond the Rocky Mountains are, on the whole, those of the northern coniferous forest. *Betula pumila, Alnus incana, Larix laricina, Salix candida, Epipactis tesselata,* and *Aster lindleyanus* (Fig. 14 to 19) are plants of this group in Ohio.

The Ohio distribution of all the northern species is similar. They occur mainly on the lake plains in the northern part of the state and have scattered stations in other favorable habitats as far south as the margin of Late Wisconsin glaciation. The occurrences on the western part of the Wisconsin drift are not as numerous in general as those elsewhere on the drift area. Usually they are not found on the the Illinoian Till Plains or the Allegheny Plateau.

The presence of these species in Ohio and their distributions there can be explained on the basis of past climatic conditions and subsequent migrations. Most likely these northern plants migrated into Ohio in advance of Late Wisconsin glaciers and then followed the retreating glaciers northward establishing themselves in suitable habitats on the Late Wisconsin drift area. The warm dry conditions of the post-Wisconsin xerothermic period favored the destruction of these northern species in the affected area, thus accounting for their greater scarcity in the western part of the state.

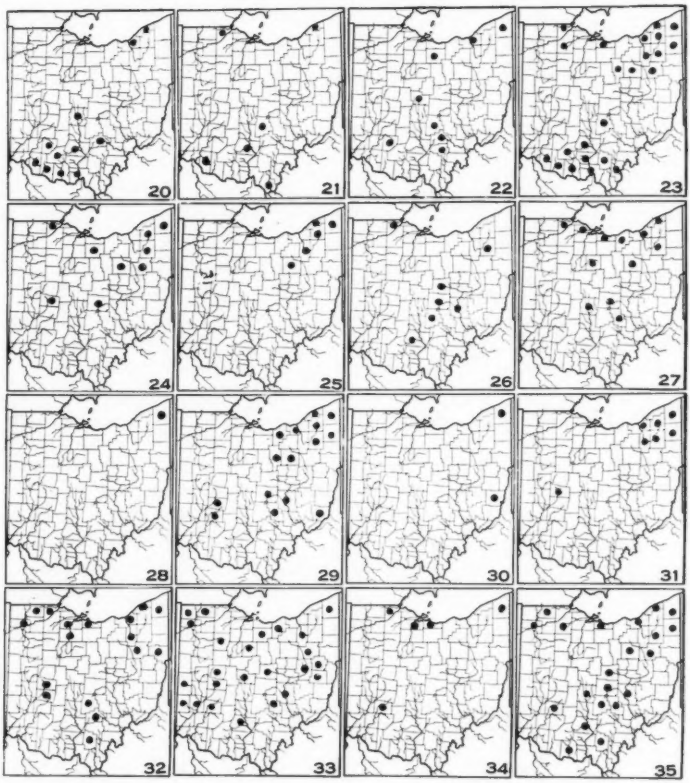
2. *North-northeastern species.*—The second major division of species of the northern element, here referred to as the north-northeastern species, are northern plants which occur also in the mountains of eastern United States, sometimes as far south as North Carolina and Georgia. In general distributional features they are similar to the northern species in that both include species which are transcontinental as well as species which do not extend farther than the Rocky Mountains in the west. Most of the north-northeastern species in this latter group have ranges which are essentially those of the hemlock-white pine-northern hardwood forest. This forest centers around the Great Lakes a little to the north of Ohio and has a southern extension in the Appalachian Mountains in eastern United States (Nichols, 1935).

The Ohio distribution of the north-northeastern species is of two main types. The first consists of those found on the northern lake plains, in the Allegheny Plateau, and on the Illinoian Till Plains. These have but few occurrences, if any, on the Wisconsin drift area. The second group, on the other hand, are those of the northern lake plains and the Allegheny Plateau which have scattered stations to the southern margin of the Late Wisconsin glaciation. These two groups have obviously had different histories and migrations in Ohio so they will be discussed separately.

Viola cucullata, V. lanceolata, V. pallens, and *Spiraea tomentosa* (Fig. 20 to 23) are representative examples of the limited number of species which are on the lake plains in the north and the Illinoian Till Plains and the Allegheny Plateau in the south. The group is characterized by the fact that there are but few or no occurrences on the Wisconsin drift between the two regions.

The southern stations on the Illinoian Till Plains may be Illinoian relics. They were able to survive on the Till Plains because Wisconsin glaciation did not cover that area and because the effects of the post-Wisconsin xerothermic period were not so pronounced there as upon part of the Wisconsin drift area (Braun, 1935).

The occurrence of these plants in the unglaciated Allegheny Plateau can



Figs. 20-35. North-northeastern Species in Ohio. Figs. 20-23. Those on the Lake Plains, the Illinoian Till Plains, and the Allegheny Plateau. 20. *Viola cucullata*, 21. *V. lanceolata*, 22. *V. pallens*, 23. *Spiraea tomentosa*. Figs. 24-35. Those on the Lake Plains, Allegheny Plateau, and Wisconsin Drift. Figs. 24-27. Far Northern Species of Boreal North America. 24. *Drosera rotundifolia*, 25. *Phegopteris dryopteris*, 26. *Corydalis sempervirens*, 27. *Veronica scutel'ata*. Figs. 28-35 Species of the Hemlock-White Pine-Northern Hardwood Forest. 28. *Acer pennsylvanicum*, 29. *A. spicatum*, 30. *Oxalis acetosella*, 31. *Trientalis americana*, 32. *Maianthemum canadense*, 33. *Fraxinus nigra*, 34. *Actaea rubra*, 35. *Aralia nudicaulis*.

be explained without taking glaciation into consideration as they may have survived glaciation there. However, the northern lake stations, because of the physiographic history of the area, must be considered post-Wisconsin and could have been reached by postglacial migrations from the adjacent Allegheny Plateau. If these plants have ever extended over the Wisconsin drift, they have been subsequently eliminated.

The greatest majority of the north-northeastern plants are those which are found in Ohio on the northern lake plains with occurences in the Allegheny Plateau and in isolated favorable habitats on the Wisconsin drift area.

There are a few far northern species of boreal North America in this group. *Drosera rotundifolia, Phegopteris dryopteris, Corydalis sempervirens,* and *Veronica scutellata* (Fig. 24 to 27) show the characteristic Ohio distributions. Pennell (1935) lists *Veronica scutellata* as common in swamps from Newfoundland to the Mackenzie, south to Virginia, Illinois, Colorado, and California, and as widespread in the Palaearctic region. He indicated that it probably survived glaciation in both eastern and western North America. It has spread onto the glaciated area in the west only slightly, mainly down river valleys. However, eastward it is now found mainly on glaciated regions.

Some of the north-northeastern species are plants which are characteristic of the hemlock-white pine-northern hardwood forest and which extend northward into the northern coniferous forest. Among these are *Acer pennsylvanicum, A. spicatum, Oxalis acetosella,* (now known as *Oxalis montana*), *Trientalis americana,* and *Maianthemum canadense* (Fig. 28 to 32). *Fraxinus nigra, Actaea rubra,* and *Aralia nudicaulis* (Fig. 33 to 35) are among the numerous examples of plants in Ohio which are important species in the climax stands of the hemlock-white pine-northern hardwoods forest (Nichols, 1935).

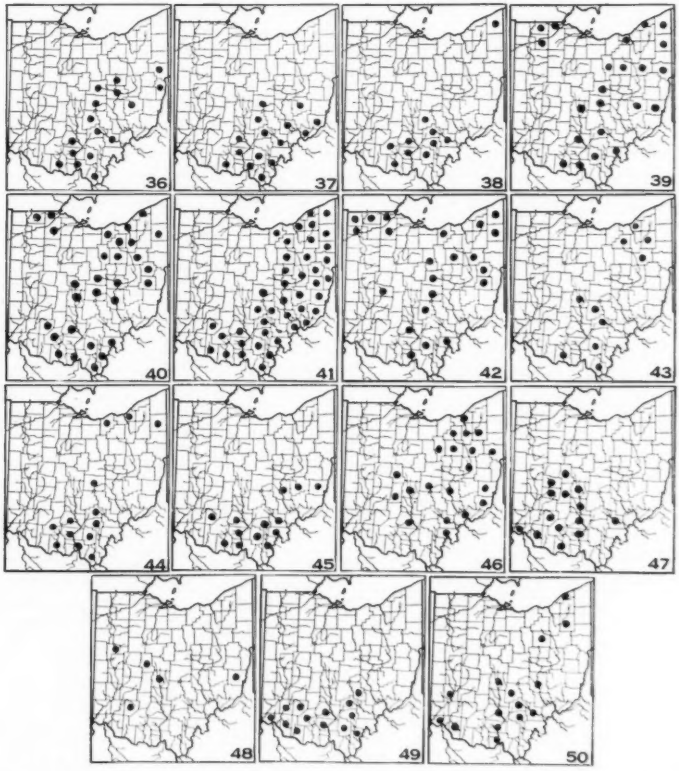
The north-northeastern species on the Wisconsin drift in Ohio are for the most part Wisconsin relics. They preceded Late Wisconsin glaciation into the area and then followed the retreating glaciers out establishing themselves rather continuously on the recently glaciated area. They have been able to survive in isolated favorable habitats where the effects of the post-Wisconsin xerothermic period and later climatic changes have not been too pronounced. However, not all the occurrences of these species in Ohio are relics. Some such as *Acer spicatum* have numerous stations in the unglaciated Allegheny Plateau. Others such as *Maianthemum canadense* have been reported in a few counties of the unglaciated Allegheny Plateau. These occurrences are not relics but are within the general range of the species. Since glaciation a few species such as *Acer spicatum* have evidently spread from the Plateau to the glaciated area so that some of the occurrences on the Till Plains may not be relics.

In contrast with the northern species, a large percentage of the north-northeastern species are those characteristic of the hemlock-white pine-northern hardwoods forest and all of them have occurrences in the Appalachian Mountains in eastern United States. For this reason the occurrences in the Allegheny Plateau in Ohio are within the range of the species. The two groups, how-

ever, have much in common both as to Ohio distributions and the past histories in the region.

B. *Appalachian Element*

About ten percent of the native vascular flora of Ohio are plants which are mainly concentrated in the eastern unglaciated Allegheny Plateau section of Ohio. These have their center of distribution in the Appalachian Mountains



Figs. 36-50. Appalachian Species. Fig. 36-43 Strictly Appalachian Species. 36. *Kalmia latifolia*, 37. *Pinus virginiana*, 38. *Gerardia laevigata*, 39. *Gaultheria procumbens*, 40. *Vaccinium vacillans*, 41. *V. stamineum*, 42. *Gaylussacia baccata*, 43. *Cypripedium acaule*. Figs. 44-46. Appalachian and Ozark Species. 44. *Iris cristata*, 45. *Gillenia stipulata*, 46. *Magnolia acumminata*. Fig. 47-50. Interior and Ozark Species. 47. *Psoralea onobrychis*, 48. *Rudbeckia fulgida*, 49. *Habenaria peramoena*, 50. *Eupatorium sessilifolium*.

of eastern United States. Some are rather general in southern United States and others have migrated into the glaciated part of the province.

In Ohio some of the species are limited to the unglaciated Allegheny Plateau. *Kalmis latifolia, Pinus virginiana,* and *Gerardia laevigata* (Fig. 36 to 38) are examples. Other species have migrated to the glaciated section of the Plateau and have found suitable habitats on the lake plains, the Illinoian Till Plains, or the eastern part of the Wisconsin drift if the rock substratum is suitable. *Gaultheria procumbens, Vaccinium vacillans, V. stamineum, Gaylussacia baccata,* and *Cypripedium acaule* (Fig. 39 to 43) are species which in general show this range in Ohio. Two of them, *Vaccinium vacillans* and *V. stamineum,* are local and rare on the Illinoian Till Plains (Braun, 1935).

A second major group of species which occur mainly in the southern and Appalachian regions of Ohio are those referred to by Steyermark (1934) as the Southern Appalachian Upland and Ozark species. Included here are Appalachian and Ozark species as well as Interior and Ozark species. These latter are plants not usually found in the Blue Ridge Province and so are not Appalachian in the same sense as are such other species as *Gaultheria procumbens.*

The Appalachian and Ozark species in Ohio are limited to the Allegheny Plateau or immediately adjacent areas. They are represented by *Iris cristata, Gillenia stipulata,* and *Magnolia acuminata* (Fig. 44 to 46). The Interior and Ozark species, *Psoralea onobrychis* and *Rudbeckia fulgida,* (Fig. 47 and 48) are mainly in the western part of the state with but few occurrences in the Allegheny Plateau and usually have a gap between the western stations and the eastern ones in the state. Others such as *Habenaria peramoena* and *Eupatorium sessilifolium* (Fig. 49 and 50) are general in southern Ohio ranging from the western part of the state into the Allegheny region.

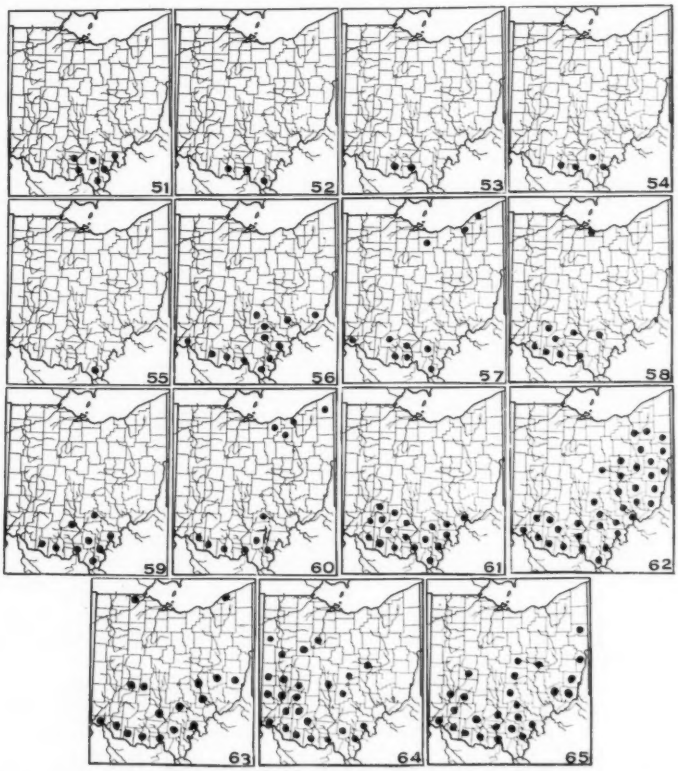
The Ozarks and Appalachian Mountains have had a similar geologic history. Both are ancient land masses where the Tertiary flora survived. Both have been centers of migration in post-Pleistocene times. The Appalachian and Ozark species of glaciated Ohio evidently have spread from the unglaciated Allegheny Plateau since Pleistocene. The Ozark and Interior species probably survived glaciation mainly to the south of Ohio and subsequently have migrated north onto the glaciated regions of Ohio.

C. *Southern Element*

About eight percent of the native vascular flora of Ohio are plants which reach their northern limits in the state. These vary in their general distributions. The largest group includes those which range from Kansas, Texas, and Florida to southern Virginia and Indiana. A few of these have extensions northward into eastern United States as far as southern New York or even Maine. Other plants have a southern interior distribution from Texas or Mississippi to southern Ohio and Virginia. There is also a small number which ranges from Mexico or Central America to Florida, Pennsylvania, and

Kansas. The southern species show three types of distributions in the state, those in the unglaciated section, those which have entered the Illinoian Till Plains, and those which have extended still farther and are represented on the Wisconsin drift. In general these southern species show similar distributions in Indiana (Parker, 1936).

Chionanthus virginica, Bignonia capreolata, Rhamnus caroliniana, Gentiana villosa, and *Passiflora incarnata* (Fig. 51 to 55) are in one to several of the



Figs. 51-65. Southern Species. Figs. 51-55. Those in the Unglaciated Section. 51. *Chionanthus virginica,* 52. *Bignonia capreolata,* 53. *Rhamnus carolin'ana,* 54. *Gentiana villosa,* 55. *Passiflora incarnata.* Fig. 56-60. Southern Species which have extended themselves onto the Illinoian Till Plains. 56. *Aesculus octandra,* 57. *Diodia teres,* 58. *Rhexia virginica,* 59. *Lobelia puberula,* 60. *Tipularia discolor.* Figs. 61-65. Southern Species which have extended themselves still farther and are on the Wisconsin Drift. 61. *Liquidambar styraciflua,* 62. *Smilax glauca,* 63. *Diospyros virginiana.* 64. *Hydrophyllum macrophyllum,* 65. *Hydrangea arborescens.*

most southernly counties of the unglaciated Allegheny Plateau. Although the Ohio distribution of this group is similar to that of a group of the Appalachian element, the general distributions of the two are different. The southern plants are general in the south but not in the higher Appalachian Mountains. Although some of the Appalachian species are rather general in the south, they are more concentrated in the Appalachian Province. These southern plants probably survived glaciation in Ohio where they are now found and hence may be considered relics of the Tertiary flora.

In the second group are the southern species which have spread onto the Illinoian Till Plains. They have but few or no extension on the Wisconsin drift area. *Aesculus octandra, Diodia teres, Rhexia virginica, Lobelia puberula,* and *Tipularia discolor* (Fig. 56 to 60) are in a half dozen or more counties in the unglaciated Allegheny region and the Till Plains; the last, *Tipularia discolor,* also occurs in several counties in the northeastern part of the state. Before its Ohio distribution was as completely known as it is at present, it was listed by Schaffner (1932) as characteristic of the northeastern or glaciated Allegheny Plateau.

The southern plants in the third group have been able to extend their ranges in the state beyond the unglaciated Allegheny Plateau and the southern Illinoian Till Plains onto the Wisconsin drift and the glaciated Allegheny Plateau in some instance. *Liquidambar styraciflua* (Fig. 61) is general on the southern half of the Illinoian Till Plains and the Allegheny Plateau. It also has one station on the Early Wisconsin drift area in Greene County. *Smilax glauca* (Fig. 62) which is common on the Till Plains (Braun, 1935), has spread onto the glaciated Allegheny Plateau also. *Diospyros virginiana, Hydrophyllum macrophyllum,* and *Hydrangea arborescens* (Fig. 63 to 65) are farther north on the Wisconsin drift than any of the others, but still belong largely to the southern half of the state.

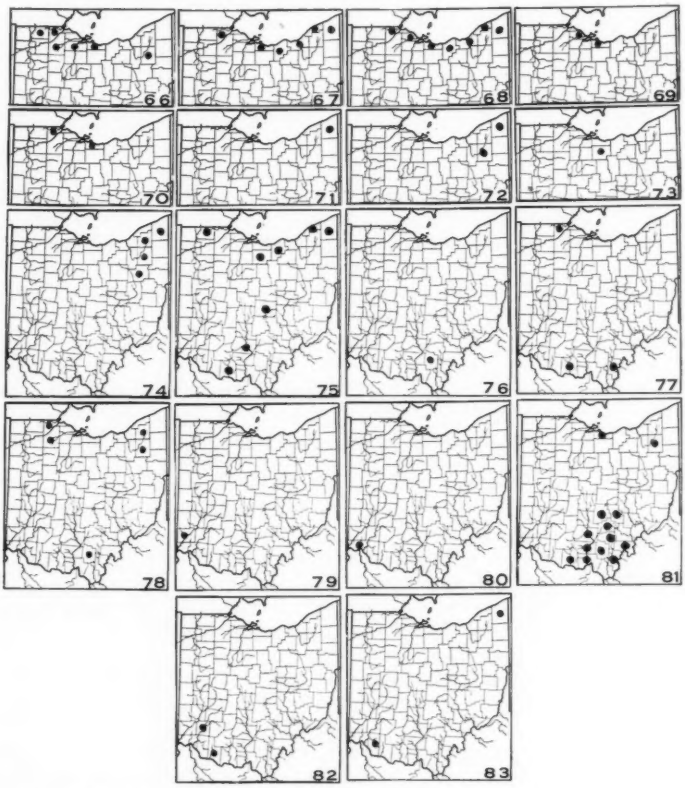
The southern species are concentrated in the southern half of the state. In post-Pleistocene times some of them have spread onto the glaciated regions. Many of the species have distributions characteristic of a large group of advancing plants. A few have occurrences along the Great Lakes in addition to the ones in the southern part of the state. These northern stations have been reached by migrations either through eastern routes or along Pleistocene connections of the Mississippi River.

In contrast with the northern element, the southern species have entered the glaciated area later and, on the whole, represent advancing rather than retreating species. Some as *Passiflora incarnata, Rhamnus caroliniana,* and *Bignonia capreolata* have apparently reached their northern limits under existing conditions and are now stationary; others as *Smilax glauca* and *Liquidambar styraciflua* are still advancing.

D. *Coastal Plain Element*

The coastal plain flora is composed of species of acid bogs, sand barrens, marshes, and savannahs found along the eastern coast of North America from the Gulf of Mexico or Florida north to New Jersey and occasionally to Cape

Cod, Nova Scotia, and Newfoundland. It does not include species of the coast which are general elsewhere nor the flora of the salt marshes and estuaries (Peattie, 1922). The coastal plain species show two main types of distributions, those which have occurrences outside the coastal plain only in the adjacent Appalachian Province and those which have stations along the



Figs. 66-83. Coastal Plain Species. Figs. 66-74. Coastal Plain Species limited to the Lake Plains and Adjacent Areas in Northern Ohio. 66. *Lupinus perennis*, 67. *Euphorbia polygonifolia*, 68. *Cakile edentula*, 69. *Hypericum gymnanthum*, 70. *Juncus scirpoides*, 71. *Hottonia inflata*, 72. *Myrica carolinensis*, 73. *Linaria canadensis*, 74. *Hydrocotyle umbellata*. Fig. 75-78 Coastal Plain Species with occurrences in the Unglaciated Allegheny Plateau in Ohio. 75. *Bartonia virginica*, 76. *Viola primulifolia*, 77. *Polygala cruciata*, 78. *Xyris flexuosa*. Figs. 79-83. Mississippi Embayment Species. 79. *Carya illinoensis*, 80. *Spermacoce glabra*, 81. *Betula nigra*, 82. *Fraxinus profunda*, 83. *Ranunculus pusillus*.

Great Lakes. Many of the latter group occur also in isolated locations in the Appalachian Province. Representatives of both types are in the coastal plain element in Ohio.

In Ohio the coastal plain species display three types of distributions, those found on the lake plains and adjacent areas in the northern part of the state, those with occasional stations in the unglaciated Allegheny Plateau and those mainly along streams in southern Ohio, the Mississippi Embayment species.

Lupinus perennis, Euphorbia polygonifolia, Cakile edentula, Hypericum gymnanthum, Juncus scirpoides, Hottonia inflata, Myrica carolinensis, Linaria canadensis, and *Hydrocotyle umbellata* (Fig. 66 to 74) are coastal plain species limited to the lake plains and adjacent areas in the northern part of the state. The last species, *Hydrocotyle umbellata,* is one of the species listed by Fernald (1937) as indigenous to the coastal plain of Virginia.

Bartonia virginica, Viola primulifolia, Polygala cruciata, and *Xyris flexuosa* (Fig. 75 to 78) are species which have occurrences in the unglaciated Allegheny Plateau in Ohio. In addition they may have stations in the northern part of the state. Fernald (1937) lists *Polygala cruciata* as a coastal plain species ranging along the coast and the gulf with isolated stations near or about the Great Lakes and *Xyris flexuosa* as a typical plant of the Pine Barrens of Virginia.

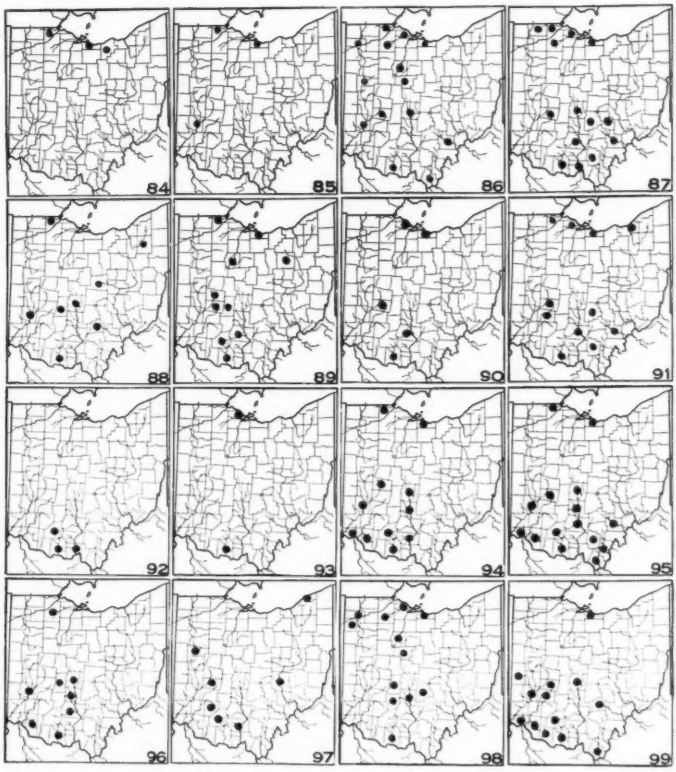
Carya illinoensis, Spermacoce glabra, Betula nigra, Fraxinus profunda, and *Ranunculus pusillus* (Fig. 79 to 83) are Mississippi Embayment species which migrated into southern Ohio along streams. The last, *Ranunculus pusillus,* also occurs in Ashtabula County in northern Ohio. The southern Ohio occurrences of this species in Clermont County and those of *Fraxinus profunda* in Warren and Brown Counties are in the swamps of the Illinoian Till Plains. *Carya illinoensis* is on the alluvial plains in Butler County, and *Spermacoce glabra* is on the Ohio River bank in Hamilton County. *Betula nigra* is present in the Ohio valley in Indiana but not in southwestern Ohio. In Ohio it is mainly in the Scioto drainage in the southern part of the state ranging northward to Fairfield, Perry, and Portage Counties. Its Ohio distribution perhaps reflects migrations along the preglacial Teays River.

The only outlet of the glacial Great Lakes that seems to have served as a westward migratory path from the Atlantic Coastal Plain into northern Ohio is the Hudson Mohawk outlet. As some of the coastal plain species have rather high migratory capacities, a few have extended themselves along the lake plains and onto the northern Wisconsin drift in suitable locations.

However, westward extensions along the outlets of the glacial Great Lakes do not represent the only intepretation given for the occurrences of these species along the Great Lakes. Pennell suggests that the lake stations of *Linaria canadensis* may be due to its survival in the Wisconsin Driftless area during glaciation and its subsequent eastward migration. He believes it is also conceivable that postglacial migrations may have taken place along the Mississippi River (Pennell, 1935). This interpretation is based primarily upon the distribution of the species. It is common along the Atlantic coast from Florida to Massachusetts, local inland in the Appalachian Mountains, and

occurs frequently inland along the Great Lakes, and is common in the Driftless area of Wisconsin.

The isolated occurrences of coastal plain species in sections of the Appalachian Plateau may be interpreted in two ways. They may be Tertiary relics, having been in the Appalachian region before migrating to the emerging Coastal Plain or they may have migrated to the Appalachian region from the Coastal Plain. It is likely that each of these has been true for certain species.



Figs. 84-99. Western Species. Figs. 84-91. Widespread Western Species. 84. *Hedeoma hispida*, 85. *Gentiana puberula*, 86. *Solidago rigida*, 87. *Liatris scariosa*, 88. *Castilleja coccinea*, 89. *Heliopsis scabra*, 90. *Draba caroliniana*, 91. *Asclepias verticillata*. Fig. 92-99. Western Species near the Eastern Margin of their Range in Ohio. 92. *Aster oblongifolius*, 93. *Viola pedatifida*, 94. *Eupatorium altissimum*, 95. *Kuhnia eupatorioides*, 96. *Hypericum cistifolium*, 97. *Artemisia ludoviciana*, 98. *Asclepias sullivantii*, 99. *Dodecatheon meadia*.

Viola primulifolia (Fig. 76) has been considered a relic on the Cumberland Plateau of Kentucky, having been in the Appalachian Province before the segregation of floras in Late Tertiary or early Pleistocene. At this time elevation took place in the region changing the environment and causing the segration of floras. Some species went onto the newly emerging Coastal Plain and are among those known today as the coastal plain species (Braun, 1937). This seems to be the logical explanation for the Ohio Allegheny Plateau occurrences of *Viola primulifolia, Polygala cruciata,* and *Xyris flexuosa* (Fig. 76 to 78).

The Mississippi Embayment species are plants of southerly distribution which are rather general on the Mississippi Embayment section of the Coastal Plain. The Mississippi Embayment and river banks form a continuous favorable habitat for the northward migration of these species into southern Indiana and Ohio. The general distribution of these species, as well as their Ohio distribution, is a reflection of the paths of migration that they have taken to reach their present northern limits.

E. *Western Element*

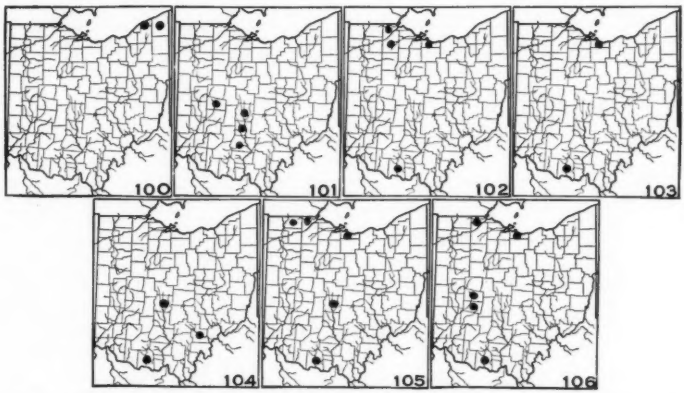
The western element in Ohio consists of species which are characteristic of both the wet or lowland prairies and the dry or upland prairies as defined by Weaver and Fitzpatrick (1934). However, many of the species which are in the lowland prairies in the west are confined to dry prairie habitats in southern Ohio. The western species found in Ohio show three general types of distributions. Some are widespread ranging to the east coast of United States in favorable habitats. However, most of the characteristic prairie species are more limited, either near their eastern limits in Ohio or occurring there as disjuncts.

The widespread western species in Ohio include those which have a limited range in the state and others which are well distributed in prairie habitats throughout the state. *Hedeoma hispida* (Fig. 84) is confined to the lake plains. *Gentiana puberula* (Fig. 85) has an occurrence on the Wisconsin drift in addition to the lake plains occurrences. *Solidago rigida* and *Liatris scariosa* (Fig. 86 and 87) are fairly widespread dry prairie species which have stations along the lake plains, on the Wisconsin drift, and also in the southern unglaciated part of the state. *Castilleja coccinea, Heliopsis scabra, Draba caroliniana,* and *Asclepias verticillata* (Fig. 88 to 91) also have at least one occurrence on each of the three major age areas of the state.

The western species which are near the eastern margin of their ranges in Ohio usually have stations in the southern unglaciated part of the state. One of them, *Aster oblongifolius* (Fig. 92), is limited to the southern part of the state. It is listed as a lowland prairie species in the west but is a pioneer in the dryest and barest places in the prairie areas of Adams County. *Viola pedatifida* (Fig. 93) is in Adams County and also in Erie County along the lake plains. However, most of the western species which are near the margin of their ranges in Ohio have stations on all three of the major age areas of the state. Examples are *Eupatorium altissimum, Kuhnia eupatorioides, Hyper-*

icum cistifolium, Artemisia ludoviciana, Asclepias sullivantii, and *Dodecatheon meadia* (Fig. 94 to 99). These are listed as lowland prairie species but the southern Ohio occurrences of some are not in the wet prairies. *Eupatorium altissimum* is generally in dry habitats in the southwestern part of the state. *Dodecatheon meadia* is usually in wooded areas on steep hillsides in southern Ohio, although in Adams County it is in prairie patches.

Of the prairie species which occur as disjuncts in Ohio, one, *Artemisia gnaphalodes* (Fig. 100), is limited to the lake plains. *Kuhnia glutinosa* (Fig. 101) has no recorded stations on either the lake plains or the southern unglaciated part of the state. *Senecio plattensis* (Fig. 102) is in several lake counties and in Adams County in southern Ohio. *Linum sulcatum* (Fig. 103) is in Erie County in northern Ohio and in Adams County in the southern part of the state. *Liatris cylindracea* (Fig. 104) is in Franklin County and in two counties in the southern unglaciated region. It is a lowland species in the prairies of the west but in Adams County it is in a dry prairie community. *Helianthus occidentalis* and *Liatris squarrosa* (Fig. 105 and 106) have occurrences on the lake plains, the drift area, and in the southern unglaciated part of the state.



Figs. 100-106. Western Species Occurring as Disjuncts in Ohio. 100. *Artemisia gnaphalodes,* 101. *Kuhnia glutinosa.* 102. *Senecio plattensis,* 103. *Linum sulcatum,* 104. *Liatris cylindracea,* 105. *Helianthus occidentalis,* 106. *Liatris squarrosa.*

The prairie species in the unglaciated part of the state are considered relics but the several workers do not agree upon their age. They are interpreted as relics of a former prairie extension into the state in pre-Illinoian times (Braun, 1928). Others believe the evidence is not sufficient for such an interpretation and that they are post-Wisconsin (Transeau, 1935). There are, however, a number of species, as illustrated by *Senecio plattensis, Viola pedatifida,* and *Linum sulcatum* which occur in the Adams County prairies and not in the prairies on the Wisconsin drift. With these Adams County

occurrences, there are also a number of southern xerophytes, as *Agave virginica*, which reach their northern limits there.

The numerous prairie communities on the Wisconsin drift and the lake plains are relics of the post-Wisconsin xerothermic period. The dry and warm conditions that prevailed then permitted the eastward migration of prairie species into the state. As conditions again became more humid, forest species were able to invade many of the prairie communities.

Phytogeographical Areas

Schaffner (1932) suggests nine phytogeographic regions for Ohio based upon the distribution of certain species in the state. They are (1) Lake Erie Shore, (2) Sandusky Bay-Lake Erie Islands, (3) glaciated Allegheny Plateau region, (4) central non-glaciated Allegheny Plateau region, (5) southern non-glaciated Allegheny Plateau region, (6) Illinoian Till Plains, (7) Miami Till Plains, (8) Great Black Swamp area, and (9) the till plains of Williams County. Each of these areas he characterized by species which are rare or absent elsewhere. However, since the publication of the catalogue, additional stations have been recorded so that certain species are more widespread in the state than the list of 1932 indicates. In addition some of those given as characteristic of the southern Allegheny Plateau such as *Draba cuneifolia, Arenaria texana, Galacta volubilis,* and *Rhamnus caroliniana* are species of prairie patches or open woods on the dolomites of Adams County, adjacent to but not on the Allegheny Plateau.

Considering the flora the product of changing conditions and shifting migrations, one might divide the state into four major phytogeographic units based on the different age areas: (1) unglaciated southern Ohio including the Allegheny Plateau and the Central Interior Lowlands, (2) the Illinoian Till Plains, (3) the Wisconsin drift area and the glaciated Allegheny Plateau, and (4) the lake plains. In addition to the intraneous flora, each of these regions is characterized by the preponderance of species of one or several of the various floristic elements and the scarcity of species of some of the other elements.

Unglaciated southern Ohio is the region which has been open for plant occupancy and migrations the longest. The occurrence of certain southern species as *Aesculus octandra* which are general there and not elsewhere in the state, give unity to the entire southern unglaciated part of the state. However, the intraneous flora of the Allegheny Plateau includes many plants generally referred to as "Appalachian." These have a limited distribution elsewhere in the state, even in the rest of the unglaciated part of the state in some cases. While a few of these are limited to the southeastern part of the Plateau, most of them extend across the central part of the Plateau, the fourth region given by Schaffner. Examples of Appalachian plants not limited to the southeastern unglaciated Plateau are *Kalmia latifolia, Gaultheria procumbens, Vaccinium vacillans, V. stamineum, Gaylussacia baccata, Cypripedium acaule,* and *Magnolia acuminata.* In addition to the Appalachian species

and a considerable number of southern species, some of which have not spread into the glaciated area, the southern unglaciated part of Ohio has a few north-northwestern species, western species, and coastal plain species.

The Illinoian Till Plains, the second oldest unit in the state, is floristically distinct from the adjacent areas. It contains some species which are absent or rare elsewhere in the state, an endemic, *Viburnum pubescens* var. *indianense*, lacks many of the spring flowers of the rest of southern Ohio, and, exclusive of the intraneous flora, has a greater preponderance of northern species than of any other element. However, a few southern, Appalachian, and Mississippi Embayment species are in the area. The prairie species are very poorly represented.

The Wisconsin drift area includes the Miami Till Plain, the glaciated Allegheny Plateau, and the northwestern till plains of Schaffner's classification. The drift area has more northern and western plant communities than any other part of the state with the exception of the lake plains. Both types of species have resulted from post-Pleistocene migrations. The Appalachian and southern species which have extended their ranges since glaciation, are usually found northward on part of the glaciated Allegheny Plateau and also to the west on the eastern part of the drift area. On the northern part there are a few stations of coastal plain species and on the southwestern part there are a limited number of Mississippi Embayment species. Otherwise the coastal plain element is lacking.

The northern lake plains, corresponding roughly to three phytogeographic regions in Schaffner's classification (the Lake Erie shore, Sandusky Bay-Lake Erie islands, and the Great Black Swamp area) have representative examples of all the floristic elements found in the state. The lake plains are characterized by a greater concentration of coastal plain species than any other region in the state. These are mainly along the shore of Lake Erie. The lake plains also afford suitable habitats for a considerable number of prairie and northern species. In addition to these, a few southern and Appalachian plants have reached the area.

Although at least a few species of all the floristic elements are in all four of the suggested phytogeographic divisions of Ohio, the areas are distinct. The southern unglaciated part is characterized by a greater concentration of southern and Appalachian species than any other area; the Illinoian Till Plains with northern species, plants that are rare elsewhere, and an endemic; the Wisconsin drift by numerous northern and western species and very few coastal plain species; and the lake plains by most of the occurrences of coastal plain species in the state as well as by numerous western and northern species.

Summary

Intraneous species make up about sixty percent of the native vascular flora of Ohio, exclusive of the Gramineae and Cyperaceae. The remaining forty percent is composed of species which are either disjuncts or else at the margin of their ranges in Ohio. Based on their general ranges these latter species

are divided into five floristic elements, northern, Appalachian, southern, coastal plain, and western elements. The northern species represent a retreating group that entered the state during Wisconsin and post-Wisconsin migrations. The Appalachian and southern species are the oldest in the state, having survived glaciation in the unglaciated region. These include stationary and advancing species. Most of the coastal plain species entered the state rather recently when conditions were favorable for extensions along the glacial Great Lakes. Those in the Allegheny Plateau are probably relics of the Tertiary flora. The Mississippi Embayment species are at the northern limit of their range in southern Ohio. The western species are relics of xerothermic periods of the past.

The presence and distribution within the state of these various floristic elements can best be explained on the basis of past conditions and migrations as well as present edaphic and climatic conditions.

The state can be divided into four phytogeographic regions, the southern unglaciated, the Illinoian Till Plains, the Wisconsin drift, and the lake plains. These divisions are based on a consideration of the changing and shifting migrations which have occurred in each. The four are distinct even though representatives of all the floristic elements are in each.

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Postglacial Vegetation of the Driftless Area of Wisconsin

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Introduction

Pollen analysis of peat bogs has been confined largely to the glaciated regions of North America. The interpretation of postglacial forest succession and climate has likewise been concerned with the glaciated region. This paper, however, is concerned with pollen analysis of three bogs located within the driftless area of Wisconsin, and the postglacial forest succession and climate therein as interpreted from the pollen record.

In general the bogs located in the north central part of the United States have been formed directly in association with the recession of the Pleistocene glaciers. Most of the lake basins in which the bogs have been formed, originated during or soon after the retreat of one of the several stages of the Wisconsin glaciation. The peat deposits represent that which have accumulated during the estimated 25,000 to 35,000 years which have elapsed since the retreat of the last glacier. It is possible that the age of these peat deposits varies with the age of the drift upon which they lie. Voss (1937) has shown this to be true with respect to peat deposits in Illinois, where he finds peat which he estimates to be 10,000 years older than that on younger drift. Further work on bogs lying in the older drifts of the Wisconsin glaciation may show forest succession during the later part of the Wisconsin epoch.

Origin and Age of Bogs in the Driftless Area

There are few bogs in the driftless area because of the mature topography and lack of undrained areas and standing water. Most of the bodies of standing water consist of sloughs and oxbows lakes which have been formed on the floodplains of meandering streams. The method and time of origin of the bogs in this area have been described by the writer (Hansen 1933), in which he shows that lakes in which the bogs have developed had only an indirect relation with glaciation. One might like to think of these bogs as having had their origin in preglacial or at least pre-Wisconsin time, and the early pollen record as one of interglacial forests. During the recession of the Third Wisconsin ice sheet, the main streams arising in the glaciated region which flowed through or near the borders of the driftless area were at a much higher level than at present, and deposited considerable outwash in their valleys. The remnants of this outwash consist chiefly of well dissected terraces. This caused the tributaries arising in the driftless area to aggrade their valleys to meet the level of the aggrading main streams, and

Fig. 1. Map showing approximate borders of the Pleistocene drift sheets. Compiled by Voss after Leverett, Leighton, Martin; modified from Thwaites. Round dots indicate the position of bogs.

to build deltas near the mouths of the tributaries. Lakes were impounded near the headwaters of the tributaries, in which the present day bogs have been formed. Other bogs have been developed in oxbows cut by meandering streams on their aggraded floodplains after the subsidence of the main streams. The bulk of the Wisconsin outwash or the higher terraces both in the Mississippi and Wisconsin River valleys is of Third Wisconsin age.[1] The forest succession as recorded by the pollen in these bogs must necessarily be that which has occurred since the retreat of the Third Wisconsin ice, but it would

[1] F. T. Thwaites, personal correspondence.

be difficult to say how soon after the recession the bogs began the pollen record. That vegetation persisted in the driftless area during the glacial periods is very possible, and Fassett (1931) describes several relict species which he thinks survived the glacial period.

General Characteristics of the Bogs

These isolated bogs in the driftless area are probably relicts of more abundant and extensive deposits of the postglacial period. Dr. L. H. Pammel collected such plants as *Vaccinium macrocarpon, V. canadense, V. pennsylvanicum, Kalmia polifolia, Chiogenes hispidula, Sarracenia purpurea,* and *Drosera rotundifolia* in the La Crosse County bogs, but today they are seemingly extinct. In a few years all remaining vestiges of these bogs will have been removed by clearing, draining, and cultivation. The peat has become oxidized and covered with silt and sand by erosion of the adjacent cultivated hillsides. Many buried peat deposits in the coulees of the driftless area have been exposed by intrenched meandering of streams cutting through locally derived till, deposited since the advent of white man.

The bogs under consideration in this paper are known as the Tamarack Creek, Hub City, and Mormon Coulee bogs (Fig. 1). The first lies in Tama-

BY COURTESY PUBLIC MUSEUM, MILWAUKEE

The bog from the western edge of Tamarack Creek. The Tamarack stumps have been grubbed out in preparation for cultivation, and the land is being drained. The peat in this portion of the bog is from seven to ten feet in depth.

rack Creek valley in the south central part of Trempealeau County. Tamarack Creek flows into the Trempealeau River which in turn empties into the Mississippi River. There is a series of bogs in this valley; those in the lower part have been formed in abandoned oxbows, while those near the head of the valley have been formed in lakes impounded as a result of the higher level of the glacial Mississippi. The samples for this study were obtained in T. 20 N., R. 9 W., Section. 34. The present day flora of the bog consists of such typical bog plants as *Sphagnum* sp., *Larix laricina, Betula pumila glandulifera, Vaccinium macrocarpon, V. canadense, V. pennsylvanicum, Gaultheria procumbens, Gaylussacia baccata, Sarracenia purpurea, Calla palustris,* and *Menyanthes trifoliata.* Many species of mesophytic herbs and shrubs are invading the bog as clearing and draining progress.

The Mormon Coulee bog is located near the headwaters of Mormon Coulee Creek, in La Crosse County. The specific location is T. 15 N., R. 6 W., Sect. 21. Mormon Creek flows directly into the Mississippi River. This bog has been developed in a lake impounded in the upper reaches of the coulee, as the creek aggraded its valley to meet the level of glaciofluviatile deposits in the Mississippi River valley. Later the lake was drained and the stream left oxbows many of which served for the accumulation of peat. The present bog is about one quarter of a mile long, but at one time it covered much of the valley floor for two miles. There is a heavy growth of mesophytic vegetation covering the bog, and much of the Tamarack has been removed. Six inches of silt and clay have been washed onto the surface from the adjacent cultivated hillside.

The Hub City bog is located in T. 12 N., R. 1 E., Sect. 34, in the northern part of Richland County, near the junction of Pine River and Melancthon Creek. It apparently has been developed in an oxbow lake, and rests upon solid sandstone, indicating that the stream had superposed itself upon the sandstone underlying the local fill. The flora of the bog is chiefly mesophytic, but the tamarack is fairly abundant and small patches of Sphagnum are to be found. The invasion of white pine and birch indicates that the bog is fast approaching the climax. On sandstone cliffs adjacent to the bog grow such plants as *Ledum groenlandicum, Vaccinium canadense, V. pennsylvanicum, Gaultheria procumbens, Gaylussacia baccata, Larix laricina,* and *Pinus strobus.* These species likely existed in the bog at one time, but oxidation has created an alkaline condition unfavorable for their existence. The bog shows a pH. of 7.0 and the sandstone cliffs show a pH. range of 4.0 to 5.0.

Methods

Peat samples were obtained with a Davis peat sampler at six inch intervals. In preparing slides for pollen identification, deflocculation was effected by boiling 1 cc. of peat for ten minutes in 200 cc. of a weak KOH solution, washing several times with water, and then centrifuging. The residue was mixed with glycerin jelly and gentian violet stain, and then mounted on slides. A total of 150 tree and grass pollens was counted from each level, which was

used for deriving the percentages listed in the tables. In addition, many pollens of sedge, heaths, water lily, cattail, and a few of composites were noted but not used in the percentage computation, because of their non-significance. A trace of hemlock pollens was noted in several levels, as well as an abundance of tamarack in the upper levels. The average of the foot and half foot levels was used for spectrum curves, because the half foot levels alone made rather saw-toothed curves. The frequency of the pollen ran low, and as many as five slides were necessary in some levels to count the required number of pollens. The advanced oxidation of the peat is probably responsible for the lack of preservation, which fact adds to the possible sources of error which are inherent in pollen statistics.

Glacial Drifts Bordering on the Driftless Area

The youngest drift bordering the driftless area is that of the Third Wisconsin on the eastern edge (Fig. 1). A zone of pre-Illinoian lies to the north, followed by a strip of drift of Illinoian age. The western and southwestern edge is bordered by a narrow strip of Kansan drift, followed by a lobe of Iowan or Early Wisconsin; beyond which the Kansan drift is exposed to the west and southwest. The Early Wisconsin lobe is shown on maps by Antevs (1929) and Thwaites (1934), as extending southeastward to the edge of the Illinoian drift south and east of the driftless. This means that the driftless area has not been continually open for forest invasion from the southwest, but only since the retreat of the Early Wisconsin ice. The driftless area has been accessible for plant migrations during much of the Pleistocene, however, and there seems to be no reason to believe that it was not forested at least during the Wisconsin glaciation. Today spruce forects grow upon Alaskan glaciers (Washburn 1935), but there the climate is probably milder than it was in the Lake States during the glacial period and at present. The driftless area may have served as a center of plant migration into the glaciated region during the glacial and interglacial periods.

Significance of Pollen Spectrum

Coniferous

The forests of the driftless area at the time of origin of the bogs in this study, consisted chiefly of fir, spruce, and pine. The Mormon Coulee bog, which lies nearest to the western border, shows frequencies of 39% pine, 24% spruce, and 20% fir in the lowest level. This may indicate that an initial forest of fir and spruce had already been replaced largely by pine at the beginning of the bog record. In the Hub City bog, which is located nearest the eastern edge of the driftless area, there is 40% fir, 28% spruce, and 20% pine in the lowest level. The Tamarack Creek bog shows a preponderance of fir and spruce consisting of 58% and 25% respectively. Pine shows a frequency of only 6%, indicating that it was not as abundant as farther south. The other bogs, however, may have had their origin at a later time, and thus do not record this earlier forest.

BY COURTESY PUBLIC MUSEUM, MILWAUKEE

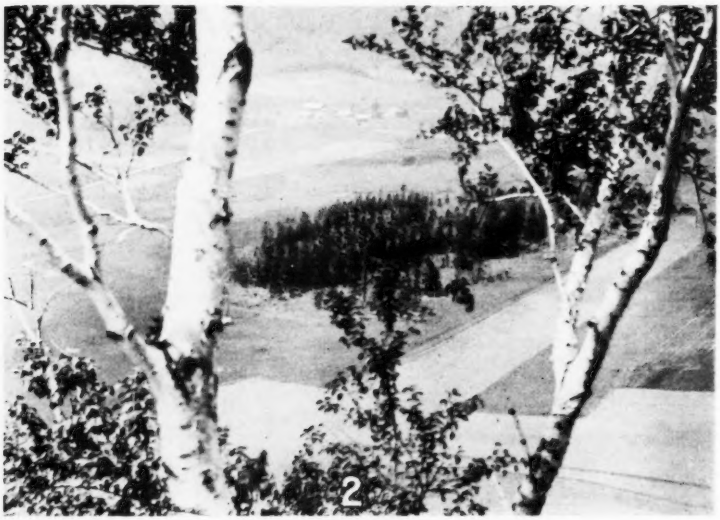
The Hub City bog from the east bluff. Mesophytic flora on the edge of the bog.

BY COURTESY PUBLIC MUSEUM, MILWAUKEE

Sandstone bluffs to the east of the Hub City bog, on which are found plants common to bogs. The upper picture was taken from this bluff.

In the Hub City and Tamarack Creek bogs spruce increases for several levels and then gradually decreases to the surface. There is a trace in all levels of the Tamarack Creek bog, but it disappears in the former at three feet. In the Mormon Coulee bog spruce decreases steadily to three feet where it disappears. In general fir decreases in frequency from the lowest levels at Hub City and Mormon Coulee, but in the Tamarack Creek bog an increase from 41% at 12 feet to 49% at 11 feet may reflect the influence of the advance of the later Wisconsin ice sheet. This is similar to the results of an analysis of a bog near Baraboo, Wisconsin, located on the Third Wisconsin drift, (Hansen 1937), and those of Voss (1934) in his work on bogs in the mid-lake region.

Pine pollens observed consist of *Pinus strobus*, *P. resinosa*, and *P. banksiana*, the first apparently being the most abundant. In all bogs pine shows a general increase from the lowest level to a maximum from which it decreases. The Mormon Coulee and Tamarack Creek bogs show a light increase at the six inch level, which may indicate deforestation by man, which left the pine standing on adjacent cliffs, thus recording a preponderance of pine during historic time. In the Hub City bog, the invasion of pine onto the bog in recent times possibly causes this slight increase.



BY COURTESY PUBLIC MUSEUM, MILWAUKEE

Mormon Coulee bog from the limestone cliffs that cap the bluffs rising from the north edge of the bog. The small size of the bog can be seen and also the cultivation of land adjacent to the bog, which allows washing of soil into the bog.

Quercus

Oak seems to be fairly well correlated in its general trend in all of the bogs. A gradual and almost constant increase to a maximum, followed by a slight decrease, and then a state of equilibrium to the six inch level is to be noted in all the bogs. The maxima are at higher levels than that of pine, showing that pine was gradually replaced by deciduous forests, as the climate became warmer. In the Hub City bog the maximum is 35% at three feet, in Mormon Coulee a maximum of 42% occurs at 4 feet, while in the Tamarack Creek bog the highest frequency is 37% at the five foot horizon. The maximum frequencies may reflect the maximum of the warm period as indicated by Fuller (1935). There is a slight and gradual decrease in oak toward the surface from these maxima, which may indicate further climatic modification or merely normal plant succession.

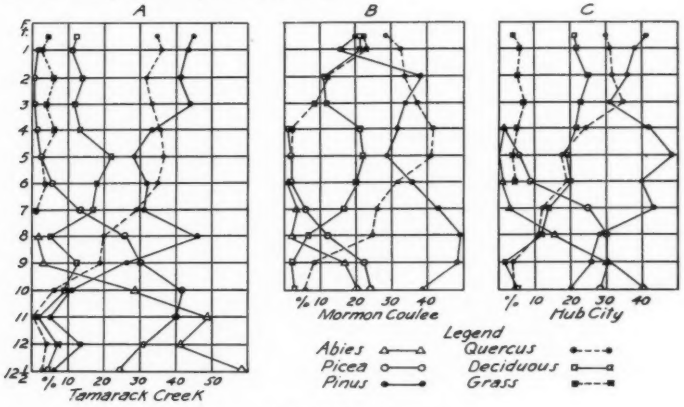


Fig. 2. Pollen Diagrams

Mixed Deciduous

The bogs of this study are located within the region occupied by the deciduous forest climax (Weaver and Clements 1938). The genera included in this group consist of Acer, Tilia, Alnus, Fraxinus, Juglans, Carya, Salix, Ulmus, Ostrya, and Populus. It seems best to discuss the spectrum as formed by the total frequencies of this group, because it gives a smoother curve. A truer picture probably can be shown of forest succession with respect to the entire group, than with the sharply fluctuating curve of each one. In general the spectrum follows rather closely that of oak, but with more fluctuation. The maximum of this group occurs about the same time as that of oak in all the bogs (Fig. 2). In the Hub City bog a maximum of 25% occurs at 2 feet, at Mormon Coulee at 5 feet with a frequency of 22%, and in the Tamarack Creek bog the frequency is also 22% at 5 feet. This likewise tends to indicate of period of warmth as depicted by the spectrum of oak. When the

total per cent of oak and mixed deciduous is taken for each level, there is a decided preponderance of deciduous over coniferous throughout the upper two-thirds of the bogs. This is also true of other bogs analyzed in the mid-lake region (Hansen 1937, Houdek 1934, Voss 1934). There is a general decrease with fluctuations from these maxima to the six inch level. In the Hub City and Mormon Coulee bogs the six inch level represents the surface of the peat, because of the silt and clay deposit on top of the peat.

Betula

Pollens of this genus include those of Betula papyrifera and Betula pumila glandulifera with a slight preponderance of the latter in most levels (Tables). This is perhaps due to the presence of the latter on the bog in the past as well as today. Paper birch is more abundant northward in the state, but it is fairly common on north exposures and as a climax tree on many of the bogs in the driftless area. The irregular and non-correlative fluctuations of this genus in all the bogs causes it to be of no indicator value. Paper birch, at present, is a subdominant and sub-climax tree in the Lake forest.

Gramineae

In many of the papers on postglacial vegetation the presence of grass pollens has not been indicated. It would seem that in the light of the present distribution of the prairies and the persistence of relict prairie areas within the deciduous forest climax region, grass pollens should be recorded to some extent in bogs lying within this region. The fact that grass pollens are thin-walled and fragile, thus preventing their preservation, may be somewhat responsible for the lack of them. Outliers of the prairie peninsula as described by Transeau (1935), extend well into central Wisconsin and the driftless area, and probably were more extensive than at present. In fact the author, in talking with old residents and pioneers in Vernon County, Wisconsin, learned that areas originally covered with prairies are now covered with a heavy growth of deciduous forest. Today many of the south exposed slopes and sandy river terraces support a growth of prairie vegetation. The previous existence of more extensive prairies than at present may be recorded by the presence of grass pollens in the upper levels of all the bogs. The Mormon Coulee bog shows a rather high frequency of 23% at 1 foot, and 22% at six inches (Fig. 2). The Hub City and Tamarack Creek bogs both show the appearance of grass at 6 and 7 feet respectively, but the frequency is lower than that of Mormon Coulee. The pollen records doubtless indicate the presence of prairies, but the forest was still dominant. The grass areas may have been local and do not necessarily indicate appreciable change in vegetative cover or climate. The appearance of grass pollens deposited concurrently in all three bogs, however, does hold some significance in relation to the present prairie peninsula and its outliers.

Conclusions

The forests that existed in the driftless area at the time of the retreat of the Third Wisconsin ice sheet, or soon thereafter, consisted chiefly of fir,

Percentages of Principal Pollens

TABLE 1

Tamarack Creek Bog

Depth in feet	12½	12	11	10	9	8	7	6	5	4	3	2	1	½
Abies	58	41	49	28	3	2								
Picea	25	31	40	42	30	26	13	6	3	2	1	1	2	
Pinus	6	13	5	11	27	46	31	32	28	34	44	41	44	45
Quercus	3	4	1	6	19	20	29	35	37	36	33	32	36	35
Mixed deciduous	5	7	2	9	12	5	17	18	22	13	12	14	11	12
Betula	2	3	2	4	8	1	8	4	7	9	5	6	4	3
Gramineae							1	4	3	6	4	6	3	4

TABLE 2

Mormon Coulee Bog

Abies	20	17	2	3	1							
Picea	24	23	12	6	2	2	1					
Pinus	39	48	49	43	36	29	32	34	38	16	20	
Quercus	6	8	24	26	32	41	42	37	34	33	29	
Mixed deciduous	3	2	7	17	20	22	21	12	11	21	21	
Betula	7	2	6	5	8	3	1	8	5	7	7	
Graminea						2	2	9	12	23	22	

TABLE 3

Hub City Bog

Abies	40	30	16	3	1		1				
Picea	28	30	30	25	9	6	2				
Pinus	20	26	28	43	40	48	42	31	36	38	41
Quercus	4	4	11	12	19	18	25	35	32	31	30
Mixed deciduous	5	2	12	14	20	19	22	23	25	22	21
Betula	2	7	2	3	6	5	3	4	2	3	3
Gramineae					5	4	5	7	5	6	4

spruce, and pine. This indicates an initial cool climate, and tends to corroborate the work of others in the mid-lake region. Tamarack Creek bog records higher frequencies of fir and spruce in the lower levels than do the other two bogs. This may mean that the former is older than the others, and thus records earlier forests, or that forest succession had progressed further to the south at the time of origin of all three bogs. Voss (1934) speaks of tundra as probably having existed west of Illinois when the Later Wisconsin ice sheet reached its maximum extension in Illinois. If the bogs of this study had their origin immediately after the recession of the Third Wisconsin ice, spruce and fir forests must have stood close to the ice front. Furthermore the area west of Illinois and southwest of the driftless area had been free of ice since the retreat of the Kansan glacier, and could have been forested and afforded a pathway for plant migration into the driftless area. The absence of a tundra record in the lower levels of bogs in the mid-lake region is explained by Sears (1935) when he states that the bog basins may have been occupied with ice until plant succession had reached an arboreal stage in adjacent areas. There is slight probability that the bog basins in the driftless area were filled with ice at any time during and after glaciation, so that their record might well show an early tundra if it had existed. The existence of a spruce forest in eastern Wisconsin between the retreat of the Third Wisconsin and the advance

of the Later Wisconsin ice, indicates the probability of forests in the driftless area long before the retreat of the Later Wisconsin ice (Wilson 1932).

The initial cool period was succeeded by a warmer period as indicated by the increase in the amount of deciduous forest. This period has persisted more or less uniformly to the present, with possibly a slight amount of desiccation in recent times as reflected by the increase of grass pollen in the upper levels of the bogs.

Summary

Pollen analysis of three bogs located within the driftless area of Wisconsin shows the forest succession which has occurred since the retreat of the Third Wisconsin glacier or soon thereafter.

The bogs have been developed in lakes formed as a result of the high level of the Mississippi and Wisconsin Rivers during the retreat of the Third Wisconsin ice.

Forest succession was apparently as follows: an initial stage of Abies-Picea-Pinus, succeeded by a Pinus-Deciduous stage, and a final stage of Deciduous-Pinus with some prairie in recent times.

In terms of climate this indicates an initial cool period, followed by a warmer period which has probably remained uniform to the present. In the upper third of the spectrum the presence of grass may reflect a slight desiccation.

The results apparently agree with most of the work previously done in the mid-lake region.

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A New Species of Agave from Trans-pecos Texas

Cornelius H. Muller

The detailed collections in the Chisos Mountains of Brewster County, Texas, by Professor O. E. Sperry and Mr. B. H. Warnock might be expected to disclose many gaps left by earlier collectors. The discovery in their collection of a new species of plant even so obvious as *Agave* is therefore not surprising. There follows a description.

Agave chisosensis sp. nov.

Folia anguste ovato lanceolata 45-55 x 6-7 cm.; spina 3-5 cm. longa attenuata lateribus applanta; margo ab apice ad basim ubique callosa; dentes 8-13 mm. longi reflexi. Scapus 2.5-3 m. longus basi 6-8 cm. crassus; inflorescentia 2.5-3 m. alta strictissima, ramulis 4-5 cm. longis, 10- vel 12-floris, pedicellis 3-7 mm. longis. Flores 4.5 cm. longi, tubo 8 mm. longo, segmentis 22 x 7 mm., filamentis basi segmentorum insertis, 40-50 mm. longis stylum aequantibus. Fructus 35-40 x 17 mm.

Acaulescent. Leaves thin, fleshy, narrowly ovate-lanceolate, broadest below the middle, about 45-55 cm. long and 6-7 cm. broad, surfaces smooth and rather glaucous green; apical spine brown or grayish, about 3-5 cm. long, acerose-attenuate, laterally much flattened, upper side round-grooved the basal four-fifths of its length, decurrent upon the leaf and contiguous with the horny margins which extend uninterrupted to the leaf-base; lateral spines brown with a glaucous bloom, flat, about 8-13 mm. long, strongly appressed-retroflexed or the apex ultimately spreading, 3-5 cm. distant from one another, the basal ones 1-2 cm. apart, occasionally reduced and ascending. Inflorescence 5-6 m. tall, scape 2.5-3 m. long, about 6 or 8 cm. thick at the base, panicle equaling the scape; basal bracts leaf-like, long-attenuate; upper bracts small, quickly drying and disintegrating. Panicle very strict and spike-like, its branches about 4-5 cm. long, densely flowered (each with 10 or 12 flowers, singly or in small groups, each on a pedicel 3-7 mm. long). Flowers golden-yellow, moderate-sized; perianth about 3 cm. long, the funnel-shaped tube scarcely 8 mm. long, the segments about 22 x 7 mm.; stamens inserted at the bases of the segments, 40-50 mm. long, at anthesis about equalling the style; ovary about 15 x 5 mm. (rapidly accrescent). Fruits numerous on each panicle branch, capsules cylindric, about 35-40 x 17 mm., prominently longitudinally veined.

TEXAS: "Basin, Chisos Mountains, Brewster County," July 13, 1937, *O. E. Sperry, B. H. Warnock,* and *W. B. McDougall* 840 (type no. 1,725,954, U. S. National Herbarium); same locality, *Sperry* without number, August 1938 (whole leaves and panicle branches in fruit); Glass Mountains, Brewster County, *Sperry* without number, August, 1938 (whole leaves).

The new species is only distantly related to the two previously known species of *Agave* in the Chisos Mountains. Despite the great similarity of its broad leaves to those of *A. Havardiana* Trelease, its very strict panicle places it closer to *A. utahensis* Engelm. in the subgenus *Littaea* (Tagliab.) Baker, section *Pericamptagave* Berger.[1] From *A. utahensis* the new species is readily distinguished by its larger leaves with longer lateral spines and horny margins extending quite to the bases, its much larger flowers with longer filaments, and somewhat larger capsules.

Agave chisosensis occurs in a relatively dry valley or broad canyon in the Chisos Mountains in scattered stands of the oak-juniper woodland vegetation type where it is associated with *Quercus Emoryi* Torr., *Juniperus pachyphlaea* Torr., and *Opuntia imbricata* (Haworth) DC. It is very likely, as indicated by its occurrence in the Glass Mountains, that this species occurs also on several of the low mountains and foothills adjacent to the Davis and Guadalupe Mountains to the north and on those of the Sierra del Carmen in Coahuila to the south. That distribution is shared by several species of other groups. The superficial resemblance of its vegetative parts to those of the common *A. Havardiana* Trelease and of its inflorescence to that of *A. lechuguilla* Torr. (see Fig. 1) apparently have been responsible for the tardy discovery of this quite distinct species. The author recalls noting numerous vegetative plants in the same locality and regarding them as depauperate specimens of *A. Havardiana* (misidentified as *A. Wislizni* Engelm.) under which species they were discussed.[2] Since no plants with the characteristically strict inflorescence of *A. chisosensis* were seen in flower in the summers of 1931, 1932, and 1933, it is logical to assume that the species is very slow in flowering and that the numerous individuals usually flower simultaneously or approximately so.

The author wishes to express his gratitude to the collectors for the unusual completeness of the material they submitted and the very helpful photographs illustrating the habit of growth of the plant, and especially to Professor Sperry, who kindly collected additional material and checked in the field the dimensions in the accompanying description.

Division of Plant Exploration and Introduction,
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Washington, D. C.

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1 Berger, A. Die Agaven, pp. 85, 105. 1915.

2 Muller, C. H. Vegetation in Chisos Mountains, Texas. Trans. Tex. Acad. Sci. **20**:3-31. 1937.

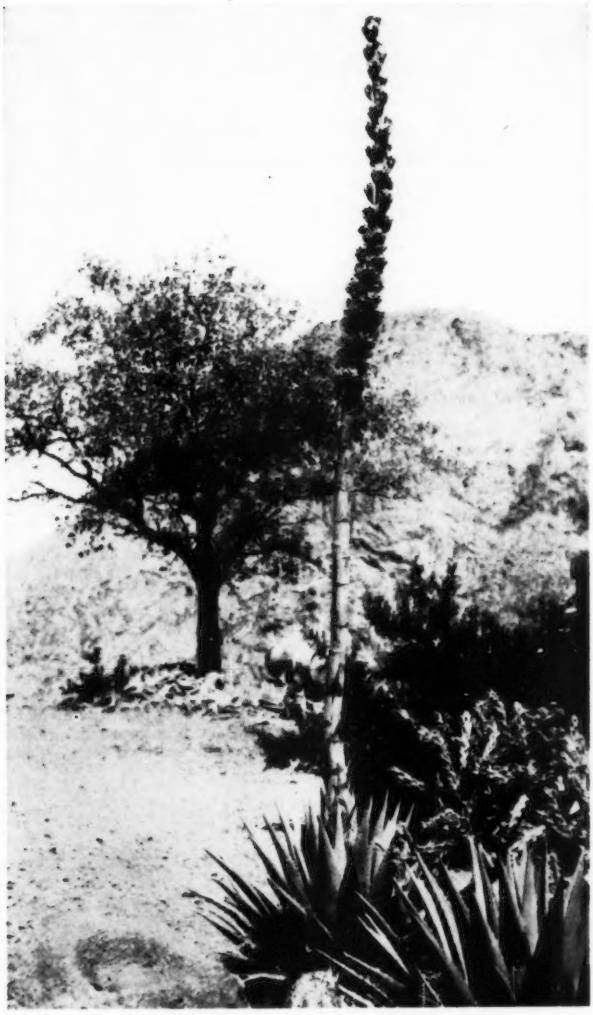

Fig. 1.—*Agave chisosensis* in the Chisos Mountains.

Notes and Discussion

Extension of the Known Geographic Range of the Striated Chipmunk (Tamias striatus)

E. Raymond Hall

Realization that the accurate mapping of the geographic ranges of mammals is facilitated by published notice of marginal occurrences, prompts me to record the following.

In the Museum of Vertebrate Zoology there is a male, skin with skull, no. 84808, *Tamias striatus venustus*, taken February 5, 1939, six miles south of Bergman, Boone County, Arkansas, by B. G. Roberts. This locality of occurrence is 44 miles northeast of Pettigrew, Arkansas, and roughly the same distance southeast of Marble Cave, Stone County, Missouri, the two localities nearest to Bergman from which this race previously has been reported (see Howell, A. H., N. Amer. Fauna no. 52, p. 23. 1929). Incidentally, Hibbard (Trans. Kans. Acad. Sci.; vol. 36, p. 238. 1933) records this race from Montgomery County, Kansas, which provides the northwestern-most station of known occurrence.

Of the next adjacent race to the northward, *Tamias striatus griseus*, I can record that it (at any rate the species *T. striatus*) occurs as far south as Peoria, Franklin County, Kansas. There, as a boy, between the years 1909 and 1913, I for the first time met with the species. As a matter of precise record I may say that the individual noticed was seen running along the top of the stone fence behind the town well on the north bank of the Maris des Cygnes River. Peoria is about 25 miles south of Lawrence, the place nearest to the northward from which this chipmunk previously has been reported.

A second specimen, no 57154, Mus. Vert. Zool., of *Tamias striatus striatus*, was taken February 26, 1933, four miles northeast of Geneva, Talbot County, Georgia, by H. E. Fuller. This place is 170 miles southwest of Young Harris, the other locality in Georgia nearest to Geneva from which the animal has been reported, and about 180 miles east of Greensboro, Alabama, where this chipmunk has been found—*Museum of Vertebrate Zoology, University of California, February 22, 1939.*

Book Reviews

THE RECENT MAMMALS OF IDAHO. By William B. Davis. The Caxton Printers, Ltd., Caldwell, Idaho. 400 pages, frontispiece of the American Moose, relief map of the principal topographical features of Idaho facing page 14. Price $5.00.

This extremely interesting and valuable work has just appeared from the press as a contribution from the Museum of Vertebrate Zoology, University of California. It is one of the best state lists that the reviewer has been privileged to read. Scarcely any review is necessary in view of the abstract which appears on pages 380-381.

There are 33 figures, the first seven of a general nature, such as: sectional profiles of Idaho; hythergraphs for Mt. Pelier and Payette and for Rupert and Sand Point; a map of the distribution of coniferous forests in Idaho; a map of the biotic areas in Idaho; a map of the type localities of mammals known from Idaho. Most of the other figures represent the distribution of the various groups of species taken up in the book. Figures 9, 11, 12 and 32 show portions of the skulls and teeth of certain mammals discussed.

Pages 99 to the conclusion are devoted to an account of each species of recent mammal (141) found in Idaho. The preceding pages are interestingly written and treat of general matters, such as: the geography of the state; floral provinces; distributional areas in the state; problems of distribution, especially as influenced by geography, geology and botany; museums containing specimens from Idaho; type localities in Idaho, numbering 43 in all, all carefully annotated. One excellent chapter is termed Gazetteer of Localities, and will prove a very useful feature not only for present day students, but also for those to follow. Any student of wild life will read with exceptional interest what the author has written on the distribution of Idaho mammals, particularly the effects of river barriers conjoined with habits, especially those of hibernation. Each species is accompanied by adequate literary citation, synonyms, distribution, description, followed by an entertainingly written account devoted to general remarks and on ecology. Each account of a species is closed with a record of its occurrence in the state. The location of each of the 3106 specimens examined, the source of original field notes and published record, on which the book is based, are plainly indicated.

Nomenclature changes are listed at the end of the book. One wonders at the raising of *Lemmiscus* to a full genus and at the same time not recognizing *Euarctos* at least as a subgenus though Miller's 1924 list is taken as a guide (p. 96).

The book, containing much new information, is a resume of long research by Dr. W. B. Davis, who himself was originally an Idahoan. That the work is a contribution from the Museum of Vertebrate Zoology, Berkeley, is enough to speak for its high character. It will be found useful by all students of mammalogy, specially those of the western states and particularly of Idaho. The fact that the United States' greatest park, Yellowstone, is adjacent to Idaho will make the book attractive for students of wild life in that park.

The book is closed with a list of literature cited, and is well indexed. It is well bound, well printed on a good grade of paper with pleasing type. Doctor Davis is to be warmly congratulated on publishing such an instructive and useful manual.

MARCUS WARD LYON, JR.

BETWEEN PACIFIC TIDES. By Edward F. Ricketts and Jack Calvin. Stanford University Press, Stanford University, California. 1939. xxii + 320 pp., 112 figs. and 46 pls.

When a scientific book is written so that it is useful and understandable both to the scientist and the layman, without detracting from its scientific value, the authors have accomplished a highly commendable work. In their "Between Pacific Tides," Ricketts and Calvin have achieved this difficult and valuable combination. Five hundred seventy-three animals from Alaska to Lower California are included in the book. These are described to some extent, though often the descriptions are inadequate, and notes on the habits, distribution and reproductive seasons of the animals have been included. The authors have shown an excellent choice in the selection of their material, for practically all of the common forms have been included.

One of the most outstanding characteristics of the book is the arrangement of the material it contains. The locality or habitat of the animals has been made the basis of arrangement. The coast has been divided into four types of habitats, namely; the protected outer coast, the open coast, bay and estuary, and wharf piling. The first two habitats have again been divided into rocky shores and sandy beaches; the bay and estuary habitat has been divided into rocky shores, sand flats, eelgrass, and mud flats; and the wharf piling has been divided into exposed piles and protected piles. All regions have again been divided into zones, or, as the authors also term them, horizons, which, in this case, is a better term. From the shore outward the four horizons are called the uppermost, high-tide, mid-tide, and low-tide, respectively. Where necessary, the horizons have again been subdivided, as, for example, zone 3, under protected outer coast of rocky shores, has been subdivided into (1) exposed rock, (2) protected rock and rockweed, (3) under rock, (4) substratum, and (5) pool. Thus it will be seen that the classifications of habitats with their subdivisions has not been carried to an extreme, yet is sufficient to greatly enhance the usefulness of the book.

For example, suppose a collector, be he biologist or layman, while investigating a region of the protected outer coast, finds a small, gray, six-rayed starfish on the side of a rock under the seaweed. Upon consulting the Contents and Directory of Habitats he will be directed to Articles 26 to 43. Under Article 30 he will find an account of this starfish, *Leptasterias pusilla*.

On the other hand, a biologist at the seashore wishing to obtain *Corymorpha palma* will find by reference to the index that this animal occurs in the mid-tide horizon on the mud flats of bays and estuaries of Southern California.

The book is well illustrated with both drawings and photographs, there being 112 figures, and 46 plates with photographs of 187 animals, though some of the photographs were made from preserved specimens.

On the whole, the book is an extremely valuable addition to our literature on the marine fauna, and the material is presented in a pleasing and interesting style.

—G. E. MACGINITIE.

VERERBUNG "ERWORBENER EIGENSCHAFTEN" UND AUSLESE. Von Walter Zimmermann. Gustav Fischer, Jena. 1938. xii + 346 pp., 80 figs. Bound RM 18.50.

The problem of the inheritance of "acquired characteristics" is undoubtedly one of the most crucial issues of any theory of inheritance and evolution. Consequently, much literature is on hand recording the pros and cons but few truly monographic treatises have ever been prepared. It is, indeed, a courageous undertaking to survey the entire field and to attempt a coherent presentation of the multitude of data and relevant interpretations. But the author is optimistic and assures the reader that the scientists agree in the main on the fundamentals once the distasteful differences of opinion largely due to terminological difficulties involved in the expression of proper concepts are

removed. Thus he aims at first to circumscribe clearly the problem and its methodological prerequisites, then to scrutinize the available information, and finally to present in review the facts and show the limitations of our knowledge.

Accordingly, the book is divided into three main parts: 1) an introduction concerned with the general background and concepts; 2) the analyses of the four main problems which are a) the possibility of change of the hereditary factors and the transmission of these in a changed state, b) the problem of the causes responsible for such changes, c) the question of the "purposefulness" of the changes, and d) the relation of cause and adaptation (selection); and finally 3) practical conclusions, mainly as they are applicable to man. Appended are comments, both caustic and explanatory, and a glossary of select terms. Extensive bibliographies are found with each major part.

A tremendous amount of material is presented though not always in the best balanced allotment of space it seems. As is but natural, considerable criticism is expressed which in turn should result in similar critical attitudes on part of the reader and active worker. However, that was very probably the intention of the author who deserves much credit for his inclusive, if not completely conclusive, treatment of this great biological puzzle.—TH. JUST.

GENMUTATION. I. ALLGEMEINER TEIL. Von Hans Stubbe. Lfg. 23 (Band II.F) Handbuch der Vererbungswissenschaft herausgeg. von E. Baur† und M. Hartmann. Gebrüder Borntraeger, Berlin. 1938. iv+429 pp., 90 figs., 130 tables. Subscription price RM 48.00, otherwise RM 60.00.

The concept of mutation is today as vital to genetics as the analysis of the heritable factors. Of the different types of known mutations the gene mutation is here subjected to a monographic treatment whereas a companion volume containing lists of mutations is scheduled for the near future. The effort which has been expended by the author in the preparation of the general treatment is evident from the admittedly incomplete bibliography which occupies 54 pp. (pp.377-429) and which is suitably arranged according to chapters. Consequently, the book represents an immensely serviceable and nearly exhaustive account of our knowledge of the gene mutation including the history of the concept, general descriptions of the nature of gene mutations, the quantitative means of analysis of spontaneous and experimental mutation rates, and general considerations of the nature of the gene. Our views of the gene are obviously still of a very general character and can best be exemplified by the following quotations (p. 368): ". . . genes are atomic unions whose structure is as yet not understood. Numerous facts like autonomy, stability, and specific mutability of genes favor an atomic union of definite structure as more probable than an amorphic body. Whether this atomic union is autonomous or, according to Koltzoff's view, a radical of a large molecule remains unsolved at present," and on p. 375: "A mutation is caused by the introduction of external energy or by changes of the energy of temperature and consists in a rearrangement of the atoms within an atomic union into another state of equilibrium; an atomic union is here regarded as a structure in which certain atoms are arranged in a certain stable position". These conclusions are presented after mature consideration of all available facts as the best interpretations possible at the moment.—TH. JUST.

ANIMALS WITHOUT BACKBONES. An Introduction to the Invertebrates. By Ralph Buchsbaum. The University of Chicago Press, Chicago, Ill. 1938. ix + 371 pp., profusely illustrated. $3.75.

The present book is the last of the "new plan texts" published and, like most of the others, marks a definite departure from conventional treatments. It was written to meet the many needs varying from work in general biology to special instruction in

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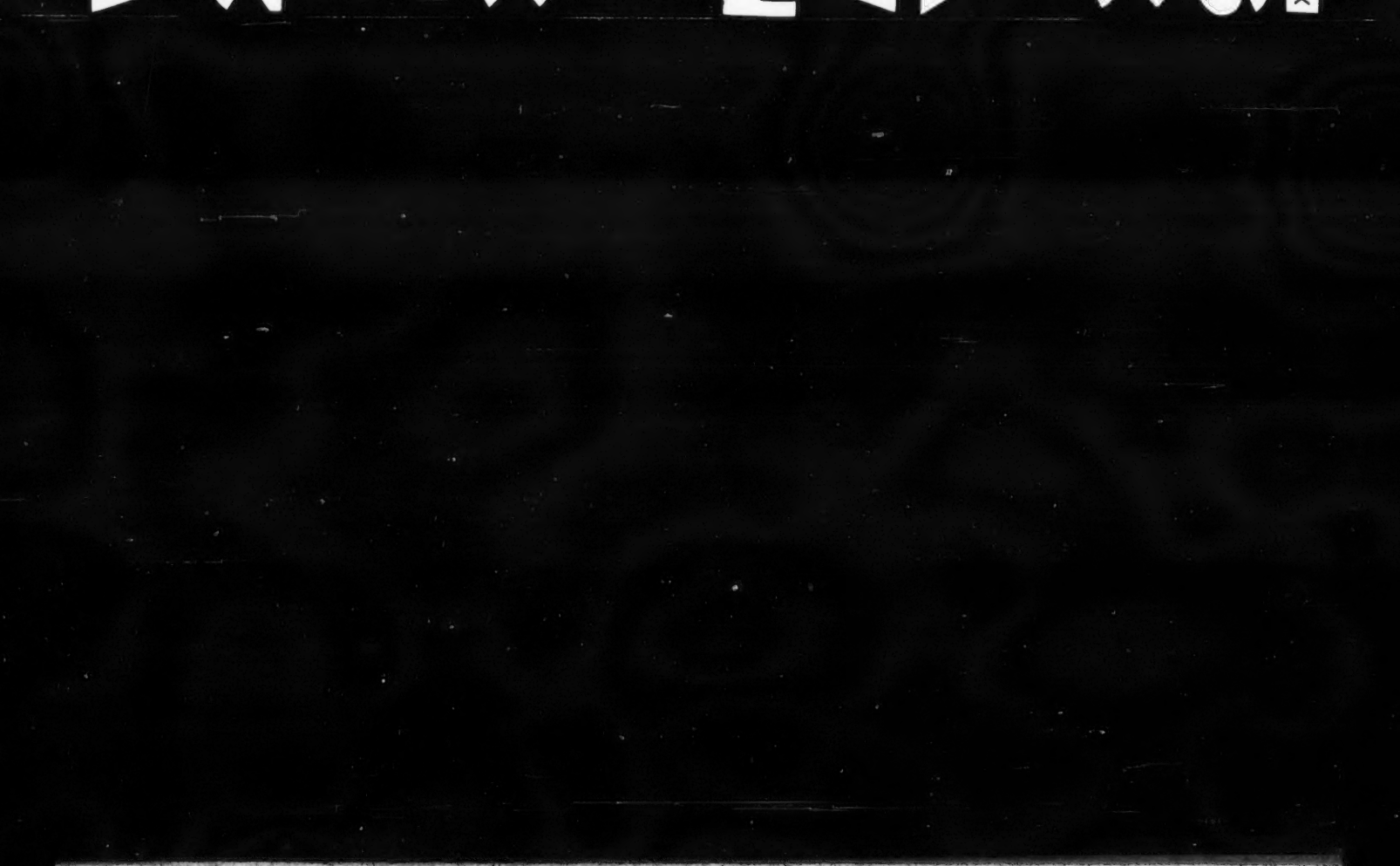
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